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Final Report

CONSTRUCTABILITY MULTIMEDIA SYSTEM WORKING MODULE

Bob McCullouch

January 8, 1998

Indiana
Department
of Transportation

Purdue
University

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Constructability Multimedia System Working Module

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by

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Joint Transportation Research Program

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16. Abstract

Constructability can be defined as incorporating knowledge into the design product or designing so it is easier to construct. Transportation facilities have suffered from this problem, with INDOT no exception. The most important feature of any constructability program is capturing field examples, commonly referred to as "lessons learned," and archiving and retrieving them into future projects that are either similar or have similar conditions in order to eliminate or prevent the same mistakes from occurring again. A mechanism or tool that can perform this task would be a valuable asset for INDOT.

A previous JHRP project titled "An INDOT Lessons Learned Constructability Program and Integrated Multimedia System" developed a working tool prototype to be used for this purpose. This prototype tool demonstrated how constructability knowledge, through computer technologies and multimedia, can be provided electronically to designers. A follow-up project was needed to move the prototype to a full working version containing the latest "lessons learned" and that work was performed on this project. A description of the product is contained in this report, as well as an explanation of how to use the product, modify it, and maintain current information based on constructability knowledge. The tool has been named DICEP (Design Integrated Construction Engineering Platform) and will be referred to by this acronym.

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Introduction

A primary factor, contributing to lack of productivity gains in the construction industry is the failure on the part of design and construction teams to effectively record, for future use, so called, 'constructability-lessons-learned.' This is not a new problem. For many years experienced construction personnel have provided input into construction projects in order to enhance constructability. Zyhaljo (1987) advised that structural engineers are still not usually trained or educated in construction methods and are therefore unaware of the impact of construction constraints on design. Gee (1989) observed that in order to shift the liability for means, methods and tasks sequences to the contractor, most designs are based on an assumed method and sequence of construction. Fisher (1991,b) claimed further, that due to the fragmentation in the construction industry, structural engineers rarely use explicit constructability knowledge when making decisions about the layout and dimensioning of structural elements. Construction systems tend to be islands of automation in specialized firms. Integration of design and construction is still at the level of face-to-face review meetings and post construction design reviews (O'Connor 1987; Tatum 1987)

Constructability has been defined as the integration of construction knowledge and experience during program development, conceptual planning, engineering design, and construction operations; to achieve project efficiency. Since developing a clear understanding of a project's objectives and priorities is the first responsibility of the owner's team, it necessarily includes construction cost, and its related schedules, quality and safety considerations. Project value engineering analysis can and should include additional consideration for aesthetics, reliability, leasability, public image, operability and maintainability, etc. (Tatum, Vanegas & Williams 1985).

Construction experience is knowledge based on methods to perform construction field operations, gathered primarily from the results of prior projects. This knowledge provides technical, operational, contractual, or administrative guidance for subsequent projects. (Reuss & Tatum 1993) The primary objective of constructability is the enhancement of project performance. This may be accomplished by using construction knowledge or lessons learned especially during the planning, conceptual and schematic design phases. Doing this at the early stages will significantly reduce construction labor and equipment cost, decrease the amount of change orders, help prevent cost overruns, lessen scope growth, and most likely minimize claims, time extensions, and litigation.

The advantages of constructability programs are well documented. In the mid 1970's Proctor and Gamble developed a manual on constructability, based on 13 in-house case studies documenting the benefits of a concerted effort (Constructability-It Works 1977). Ardery (1991) found they will pay off 10-20 times the cost of the program. The Construction Industry Institute (CII) reported that specific projects have realized a 6-23% savings and project schedule savings of up to fourteen months, by the addition of a constructability program (Constructability: Primer 1987). Fisher (1991) determined that through such programs engineers can be trained more quickly, and better decision support data and knowledge will be available. According to Jaselskis (1988), the probability of successful project schedule performance increases from 2% to 33% with a constructability program. Indeed, implementation of a constructability program seems to have a significant impact on achieving overall project success as well as better schedule performance - especially on fixed-price contracts (Jaselskis & Ashley 1991)(Ardery 1991).

Problem Statement

A previous JHRP project , "An INDOT Lessons Learned Constructability Program and Integrated Multimedia System", was performed to develop a working prototype for use by INDOT Division of Design . This prototype demonstrated how through computer hardware, multimedia technologies, and software; constructability information can be provided electronically to assist the design process. The primary objective of the system is to enhance project performance through the effective input of constructability knowledge during the planning, conceptual, and schematic design phases. This will have a very significant impact by reducing change orders, budget overruns, lessen scope growth and change, minimize claims and time extensions.

The prototype demonstrates the system capabilities. Its form is a framework and a next phase is needed to bring it to a completed mature form that can be implemented into INDOT's operations.

Project Objectives

The main objective of this project is to complete the development of the Constructability Integrated Multimedia System by taking the prototype and adding data depth to make it a viable, implementable system. In order to accomplish this main objective four goals had to be accomplished. These four are described next.

The first of these is to complete the development of a constructability system performed under the previous JHRP project described above. This system utilizes computer hardware and software to present constructability lessons learned information. This presentation is through a multimedia environment that improves the designers understanding and comprehension of the interrelationship between design and construction processes.

The second is to perform a "Beta" test of the system to identify potential "bugs" and receive input from the users regarding its operation and "user friendliness."

The third is to develop a mechanism that contains guidelines and procedures for INDOT personnel on how to operate and maintain the system with current and relevant data.

The fourth is to develop a user version on a CD-ROM disk. This version will be distributed within INDOT and externally to INDOT design consultants, contractors, other DOTs, and FHWA.

Work Plan

This project is a followup to JHRP project " **An INDOT Lessons Learned Constructability Program and Integrated Multimedia System**." This first project produced a prototype that demonstrates how through multimedia constructability knowledge can be used to enhance the design product. This project was approved to turn the prototype into a full working system for use by INDOT Design Division and INDOT consultants. The following are the activities performed to accomplish this.

The activities performed during this project were:

1. Complete the development of the Constructability Concept Database;

2. Perform a "Beta" test involving system users;

3. Collect Constructability Concept Field Data in the appropriate media form;

4. Develop System Procedures and Operation Manual; and,

5. Develop CD-ROM version.

The following is a description of each activity.

Activity 1 - Constructability Concepts Database

Constructability concepts development in the previous project identified some of the main problem areas and produced a format for describing them. This format consists of: a. *Location Logic* - this is a location label that identifies where the concept is located within the database; b. *Concept Guideline*; c. *Benefits*; d. *Reasons*; e. *Examples*; and, f. *Media data*(graphics, audio, or video). Most concepts in the original database lacked depth and needed further definition. Each of the proposed initial concepts were analyzed and reviewed to determine appropriateness, accuracy, and clarity. Additional concepts were also sought after and described in the above format. Currently there are 63 constructability concepts described in the information base. A copy of these concepts is found in Appendix D(graphics in the lessons may not appear in the print out). These concepts are organized into the four main categories of Roads, Bridges, Contracts, and Environmental. You will notice that in some concepts the embedded graphics did not print properly as well as some of the embedded notes information.

Some of the lessons have the sources identified by names in parenthesis and direct quotes from a source are enclosed within quotation marks.

Activity 2 - Beta Test Prototype

The prototype was tested for useability and implementation. Various design personnel were provided an opportunity to use the system and to solicit their opinion and make comments. The purpose of the test was to identify "bugs" , evaluate its format , and educational value. Test results were evaluated and appropriate revisions were made to the program and the information base.

Activity 3 - Collect Concept Field Data

An important part of concept development was to identify the best media form to use. The media used to explain the concept can be text, graphics, audio, and video. Actually all media forms can be used to explain a concept. Depending upon the concept media recommendations, field data capture was performed. This required coordinating with Operations Support and the Districts , project sites, dates, and times to capture and record the appropriate construction activity.

Activity 4 - Develop System Procedures and Operation Manual

INDOT will take over the ownership of the system at the conclusion of the project. To do so will require the development of procedures to operate and maintain it. This process will involve both the user of the system, currently the Division of Design, and the provider of information, Operations Support and District personnel involved with the construction projects. Therefore, instructions and guidelines were developed to instruct both of these groups in maintaining or feeding new and current information in and how to incorporate it into the system and release updated versions to the users. These instructions are found in Appendix A.

Activity 5 - Develop CD-ROM version

To distribute this system a CD-ROM version was produced. There are several reasons for selecting this technology. Because of the large data storage demands created with multi-media applications(for example one minute of video requires approximately 10 megabytes(MB) of storage space), the CD-ROM has the ability with storage capacities ranging from 600 to 800 MB to store the constructability system run time version. Version 1.0 size is approximately 330 MB(megabytes)in size. Another reason is the apparent economy associated with this technology. The new standard in PC configuration is a CD-ROM drive. Therefore, most users will have a CD-ROM drive in their machines and will not need a special expensive PC machine to run the application. The process of making the CD-ROM version requires a hardware device(CD maker) and CD development software. INDOT Division of Research has obtained both and they were used to produce the CD version. Appendix B contains the instructions for installing the CD-ROM version on a machine. Appendix C contains the User manual instructions for operating the CD-ROM version.

Conclusions

Results from this project appear to be very encouraging. The tool in its present form provides a important source of information to designers of transportation facilities. Not only constructability information but design info, construction methods, specification info, and design memorandums are included. Demonstrations have created a great deal of interest among DOT personnel, consultants and contractors. Two expected results are lower project costs and reduction of design errors.

Lowers Project Cost

Using a constructability tool during the planning, conceptual and schematic design phases, will significantly reduce construction labor and equipment cost. It will also decrease the amount of change orders, help prevent cost overruns, lessen scope growth, and most likely minimize claims, time extensions, and litigation. With this system the human design engineer is effectively involved in the implementation of constructability during design.

Eliminates Construction Related Design Errors Before They Occur

Rather than reviewing plans and specifications after the design is complete, using this tool, the integration of construction knowledge and experience is possible in the earliest stages of project planning. Designers need not rely solely on their own site experience, combined with bits and pieces of constructability knowledge published in various places, or on input from a cooperative contractor. An explicit constructability

knowledge base is economically feasible to create, update and use. The designer can see first hand the problems that design detailing can lead to, and be exposed to the full range of methods that may be utilized by contractors. A large individual investment of time and money is not required. As a result, owners need not pay the additional price for design-rework, which is less costly than construction-rework, but occurs too late to influence the major construction methods.

Costs and Benefits

This can be an effective tool for designers to incorporate construction experience into the design product. For it to be successful, it must maintained by INDOT. Maintaining will require personnel and cost money.

Benefits associated with using this tool can be quantified by using general cost saving ratios experienced in the construction industry or with a more specific estimating process. A specific estimating process was performed under the "An INDOT Lessons Learned Constructability Program and Integrated Multimedia System" project and is included in the final report on pages 146 & 147. Construction Industry Institute(**CII**) research reveals a cost savings range between 6 to 23% of construction costs through constructability programs. For INDOT with an annual construction budget of $450 million, this translates into estimated savings between $27-$100 million. This seems rather optimistic and it may be for simply using this tool. A comprehensive constructability program that utilizes this tool could possibly approach these saving levels. A NCHRP project (10-42) titled “Constructibility Review Process For Transportation Facilities” developed a Model Constructability Program for DOT organizations. The Final Report was submitted December 1996. A review of that report with implementation could produce more savings to INDOT through

constructability.

Recommendations

Constructability is not a replacement for sound design or project management principles, but is an extension and reinforcement of such principles. Furthermore, it is important, to consider the use of the tool as reducing rather than replacing the need for involving construction personnel during planning and design.

This tool should not replace actual field experience but augment it. The effort and expense to get design personnel into the field is extensive. Walter Land of INDOT Design Division estimated that it would cost $600,000 to send the Division engineers to the field for two weeks while severely impacting the work flow. Another reality with trying to obtain experience with site visits is that it is impossible to visit different projects at the right time. Through multimedia this information can be recorded and saved for future reference at the convenience of the design engineer.

The current constructability lessons number 63. A very important need is to keep the lessons current and updated. A Developer Version has been developed for this purpose and is described in Appendix A. INDOT will need resources and a commitment to carry on the effort or the information will become obsolete and the tool will lose its value and appeal.

Since INDOT uses design consultants to perform approximately 80% of design contracts, their use and involvement with the constructability tool is a necessity. Typically, consultants are required to present their qualifications during the selection process for new work. At this time, they should be encouraged to describe how they

plan to incorporate existing constructability principles; what new ideas are applicable, and what additions, depth of analysis increases, and new examples could be added to existing constructability principles. In this way the consultant becomes a more active and visible source for further depth and understanding of alternatives.

Recommended Additions to the Information Base

Design Manual

Links into and from the design manual are important. Such links could be developed from manual searches of the database.

Standard Details and Specifications

Constructability intelligence related to each standard detail and specification section could be developed by experts and stored with that detail or section in a hypermedia linked document file. Again manual searches by an expert could reveal appropriate links to the constructability and other electronic databases. Periodic updates should be performed as the database expands.

Equipment Utilization

A multimedia module that explains the utilization, requirements, and capabilities of construction equipment. This module could be used by designers to improve their understanding of construction operations, the required equipment needs, and construction methods and techniques.

Maintenance Considerations

Incorporating maintenance considerations into the design has very important life cycle implications. There is a strong tendency in design to focus on the initial cost and less on the overall or life cycle costs. High maintenance costs can offset lower construction costs so that for the life of the facility the design is not economical. A module that captures and provides this information to the designer would be useful.

Future Research

Future research in this area should again focus on adding content and quality to the constructability and related databases. Statistical user testing could be performed to evaluate alternative selection-icons, concept descriptions, and lessons learned; to be sure they include the proper content depth and presentation mediums. Contained within the 'utility' and other complex lessons learned, is the need and opportunity for several expert systems and further research to identify the best alternatives. A ongoing need for research to take advantage of the latest available technology.

Implementation Suggestions

For this to be an effective tool and INDOT receive benefits there must be some enforcement. Internally within INDOT Design Division, utilization requirements need to be developed and enforced. Information in the tool is appropriate for all the designers in the division, especially the younger ones. Externally with the consultants, enforcement will be more difficult. Perhaps, a contractual clause needs to be developed to encourage consultants to purchase and utilize the tool.

It is very important that a mechanism be placed into service to update and maintain the system. This will require resources in the form of personnel. Equipment resources for on-going development either exist or will transfer to INDOT from this project. Either an INDOT employee or an consultant will be needed to continue the development needed in the future.

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Appendix A

Developer Version

Developer Version

General

The developer version provides the capability for modifying the user interface screens. New icons can be added, existing icons deleted or modified, different or new backgrounds made, and new links established to the lesson informationbase. This version will operate off a hard drive on a multimedia development machine located in the Technical Services area. The best way to describe this version is through sample screens. The following pages contain sample screens that describe how this version can be used to update and maintain this tool.

There are two modules that the developer works with, the User Interface and the Lesson Informationbase. The User Interface is the navigational interface that consists of icons and background graphics. The user clicks on icons to locate a particular lesson. This module was developed in Visual Basic. The other module, the Lesson Informationbase, uses the software FolioViews.

The developer must understand the required files and the directory structure. This next section describes this.

Directory Structure and Required Files

The application should be placed in its own directory. This directory will contain four(4) files and at least two subdirectories The two required subdirectories are **Back** and **Icon**. The **Back** directory contains bmp files used as screen backgrounds. For the Indot version these images are sized at 636x 428 pixels and are true color or 24 bit or 16 million color. The Icon directory contains the icons. These are bmp files sized at 122 x 102 pixels and are true color. Other subdirectories may be used for storing video or sound clips.

The required files are: Indot.exe, project_name.jdb, project_name.nfo, and uparrow.bmp. Project_name can be any valid 8 character file name. The file Indot.exe has two versions. The one dated 10-1-97 runs the Views version, while the 10-10-97 file runs the Bound Views version. The CD-ROM version must use the Bound Views version. The nfo file is the Infobase that contains the lessons and is created in Folio Views. It must be created first before creating the User Interface and be residing in the same directory.

The jdb file is created by the program and contains information associated with each background and icon. The first line of the file is the number 256. This is the maximum number of icons permitted and is followed by 256 lines that contain their corresponding information. If there is a need to increase the number of icons then this file must be modified. For example, if there is a need for 400 icons then the 256 number must be changed to 400 in the first line and then additional blank lines added to reach 400 lines total. Also if a new project then the number of icons can be changed from the Options command which is located in the Edit menu option. The program can have a maximum of 16,000 icons.

Development Startup

The current version, Indot.jdb, is set up to operate from a directory named Indot. The CD-ROM version is setup the same way. To use the current version of the constructability tool a directory named Indot should be created and the files and directories described above copied in. A handy way to run the Developer version is to create a Icon on the desktop. The icon shortcut properties should read like the following:

D:\INDOT\INDOT.EXE /d /f=D:\INDOT\Indot.jdb

D is the drive letter so this may change. In the above statement a blank space follows INDOT.EXE and /d. The /d is a switch command that activates the developer version. The string "/f=D:\INDOT\Indot.jdb is the command to look for the file Indot.jdb. If the developer wants to create a new application then this string should be removed. If this part of the command was omitted then when the developer executed the statement up

through /d the menu option new project would be active and allow the developer to create a new one. If the new option was chosen the screen will look like Figure 1 shown below. Or if the developer wants to open an existing project the screen will look like Figure 2.

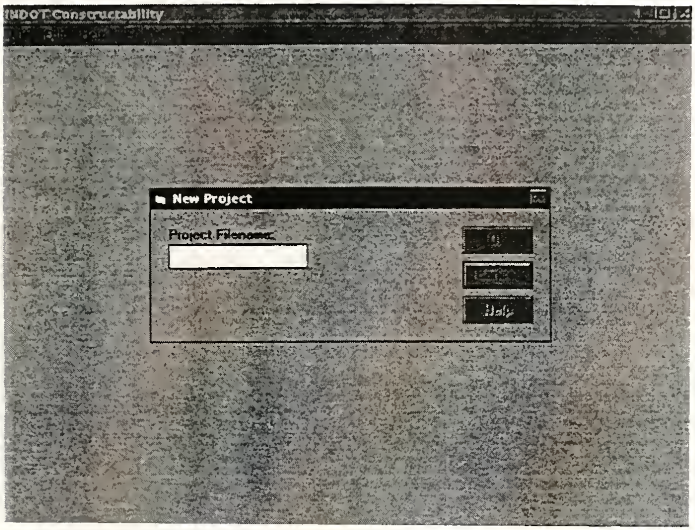


Figure 1 - New Project Screen

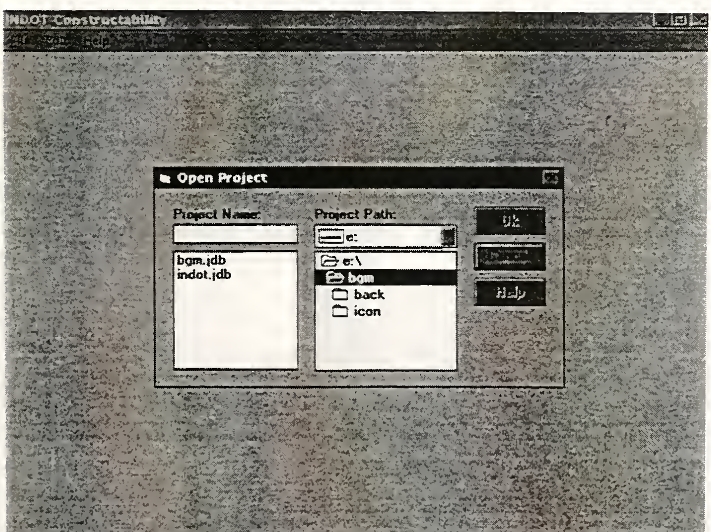


Figure 2 - Open Existing Project

Properties Window

Figure 3 below shows the Properties Window. This form appears by either selecting from the Edit menu **Insert Object** or **Properties.** If you want to create either a new icon or new background representing a new category then you would select **Insert Object.** For an existing icon that has a corresponding background, the user would right click on the icon to get it in focus, indicated by a yellow border around the icon, and select properties. From this popup form the developer creates backgrounds, icons, and relationships. This form contains data entry boxes which are described below.

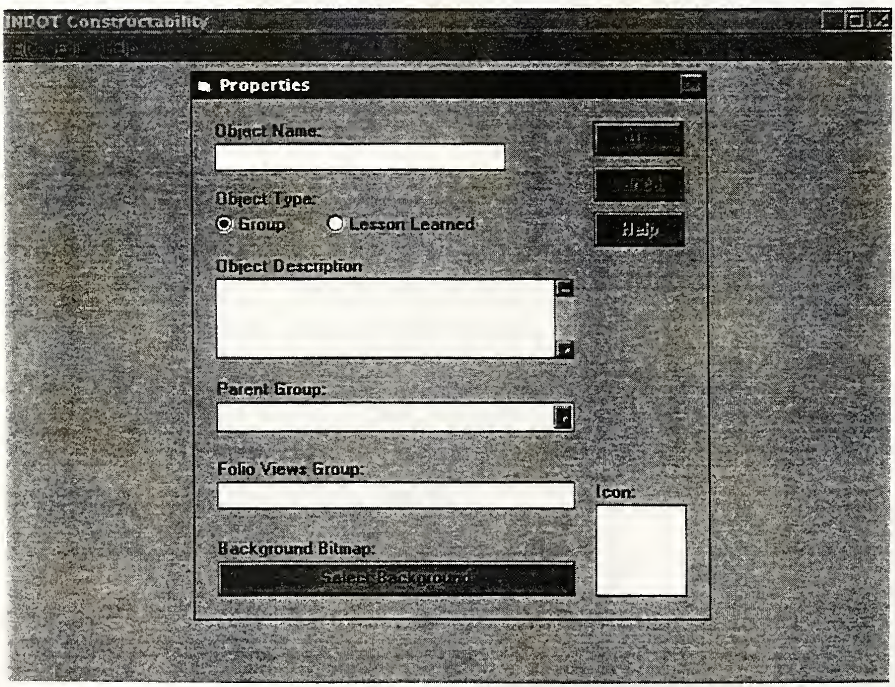
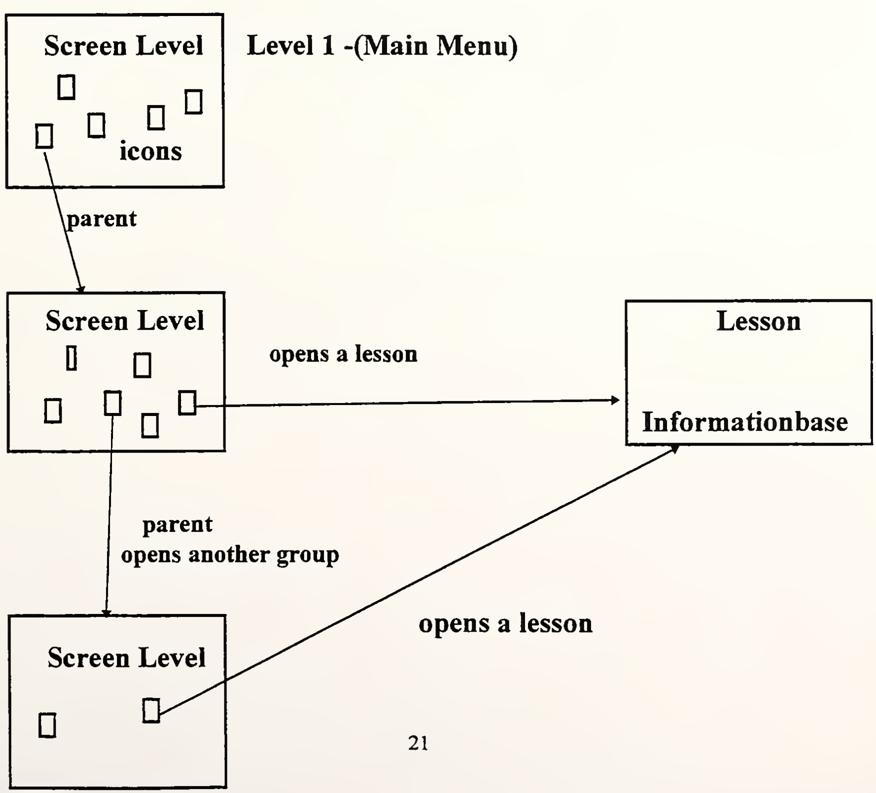


Figure 3 - Properties Window

The first one is Object name. This is the name associated with the background or the icon. If the icon represents another screen level or category then the background name

will be displayed on the green bar at the top of the screen and appended to INDOT Constructability - . For this version of the constructability tool icon names are not visible. Instead the name has been made a part of the icon. If the icon represents a lesson learned the object name is what is used to search for group names within the Folio Views Infobase, Indot.nfo. If that is the case then the object name must match exactly with the group name or the associated lesson will not be found.

The next input selection is Object Type, which is either **Group** or **Lesson Learned.** A **Group** type is for a category or screen level. A **Lesson Learned** object is an icon that has a link to a lesson in the Infobase. A description of the tool structure and how icons function is necessary. First there is no limit to the number of screen levels. The first screen, called the main menu, can contain multiple icons that represent categories. Each of these categories or screen levels contains icons to other categories or to lessons. The below diagram is a visual description of the structure.



The next input window is **Object Description**. Object Description is an optional input field because it is not displayed to the screen. It is only recorded as a descriptor in the Indot.jdb file.

Parent Group displays the name of that Object's parent. In the above diagram you will see that the parent group in the previous one in the structure. This window has a drop-down list that displays all the parent names.

Folio Views Group window is where the group name is entered if the object is a Lesson Learned. Again the Object Name must match exactly with the Folio group name which is entered here(the match is case sensitive).

At the bottom of the properties window are the input mechanisms for entering a background and icon. To enter a background click the **Select Background** button and the Properties Window will change to look like Figure 4.

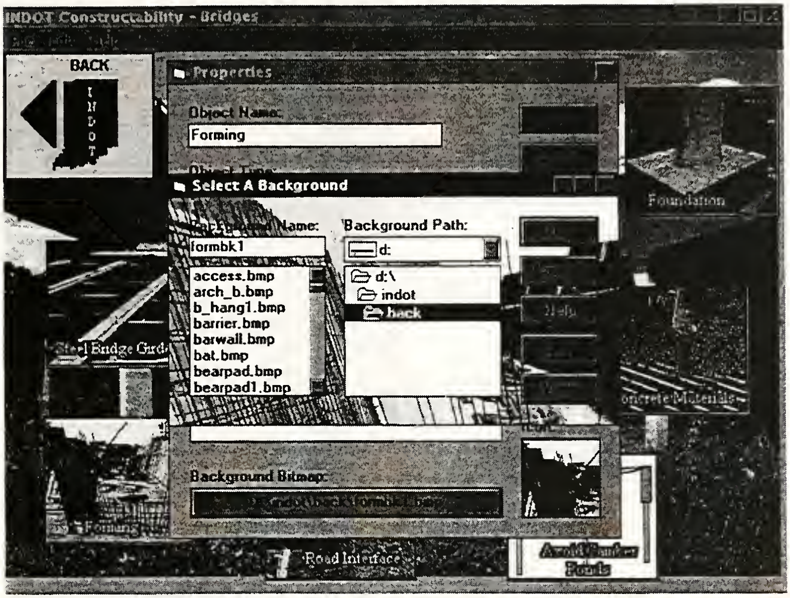


Figure 4 - Select Background Popup

On this popup the developer can search for a directory that contains background files. When a file is selected its image will appear in the background to identify itself. To confirm the selection, click the O.K. button. Clicking the **View** button will display the bitmap on the screen. To return back to this dialog box click on the bitmap. Clicking the **Clear** button will clear the bitmap from the background

To select an icon click inside the box beneath the word Icon. This will cause the Properties Window to look like Figure 5.

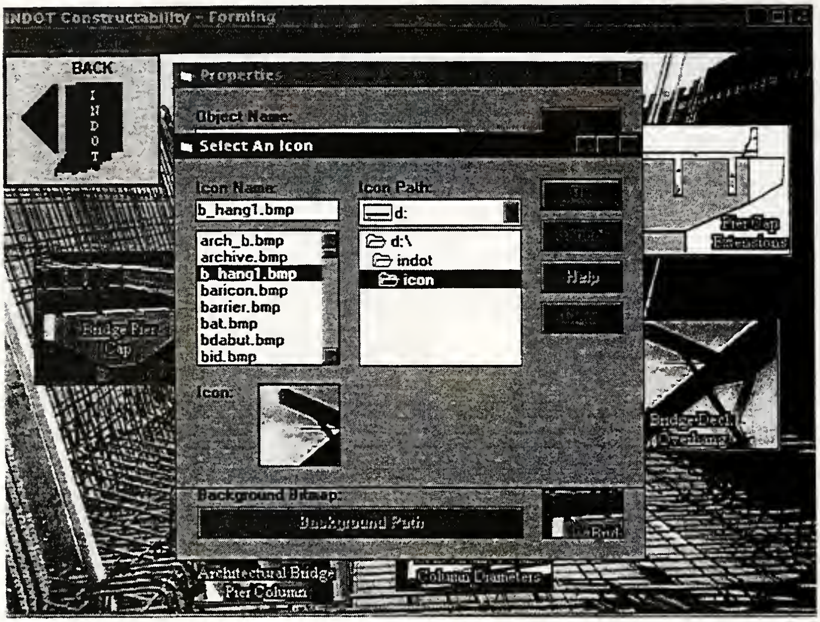


Figure 5- Icon Selection Window

Directories can be searched and a file selected whose image is displayed in the small window. To select a file click the O.K. button. The **Clear** button clears the bitmap.

If the object is a Lesson Learned then no background is required.

Menu Options

The menu bar has three options: **File**, **Edit**, and **Help**. Click the mouse on one and a drop-down box appears. When **File** is selected the drop-down has the following options:

New Project
Open Project
Save Project
Close Project
Exit
Exit Without Saving

You will notice that New Project and Open Project are grayed out. They cannot be accessed because they are only active when starting a new project and opening an existing one. See the previous section on **Development Startup**.

Save Project saves all the modifications into the .jdb file.

Close Project closes everything and returns the developer to the screen shown in Figure 6 and doesn't update the .jdb file. So be careful about closing because the changes will not be recorded.

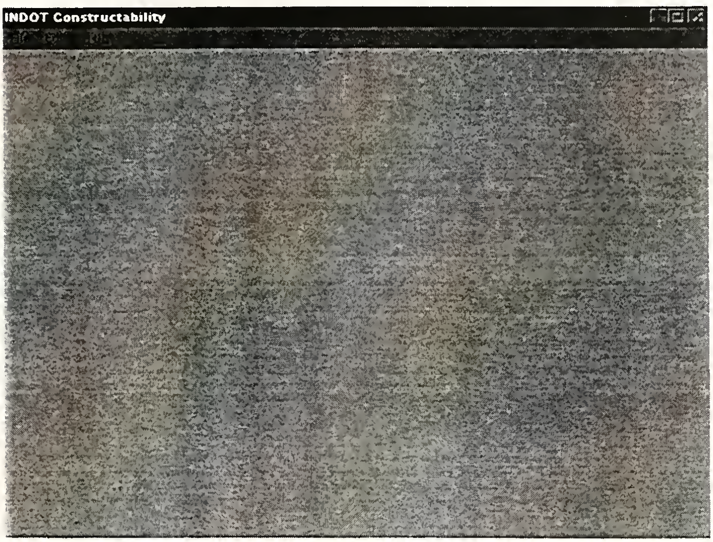


Figure 6 - Close Project Screen

Exit causes the application to quit and records all changes to the .jdb file.

Exit Without Saving quits but no changes are kept.

Selecting **Edit** the drop-down has the following values:

Insert Object
Delete Object
Auto-Insert Category
Options
Properties

Insert Object gives the capability to add new icons. When this is selected the Properties Window appears and the icon is defined through the properties values. This was described earlier in this manual.

Delete Object provides the capability to delete icons. To delete an icon and its properties, it must be in focus. To focus an icon click on it with the right mouse button. It will be in focus when a yellow perimeter band appears around the icon. The icon can be relocated on the screen when it is in focus and is moved by holding down the right mouse button.

Auto-Insert Category is an extra feature that creates three icons on the current focused object. The three icons have the titles, Site Mgmt Issues, Methods, and Tools/Materials. This option may not be used very often but it is available for automatically generating these grouping s.

Options is grayed out since the number of icons cannot be changed once a project has been set up. The only way to alter this is to manually change the .jdb file.

Properties pulls up the Properties Window of the icon in focus. From the Properties Window, icon values can be changed.

A Final Word of Caution - When making modifications to the project use Save Project frequently and always use the Exit option.

This manual is to be used by someone making modifications to the existing project or for creating a new project. The **User Manual** provides instructions for the user on how to operate the Constructability Tool.

Information Base Lesson Learn

Lessons are described in FolioViews. When a new lesson is added it must be placed in the proper location and then grouped and named. The group name must match the name associated with the Lesson icon or a match cannot be made in the query process. Figure 7 shows an sample grouping inside Folio. To establish a new group , highlight the text with the mouse and choose the Group menu option under Customize on the main menu bar. Hyperlinks are created through Program or Object Links under Customize. Video and audio files are program links and graphics are object links.

Video Files

In this latest release version several video files have been compressed with a compressor named ClearVideo. To play these files on a user machine the install program has been modified to copy the required files.

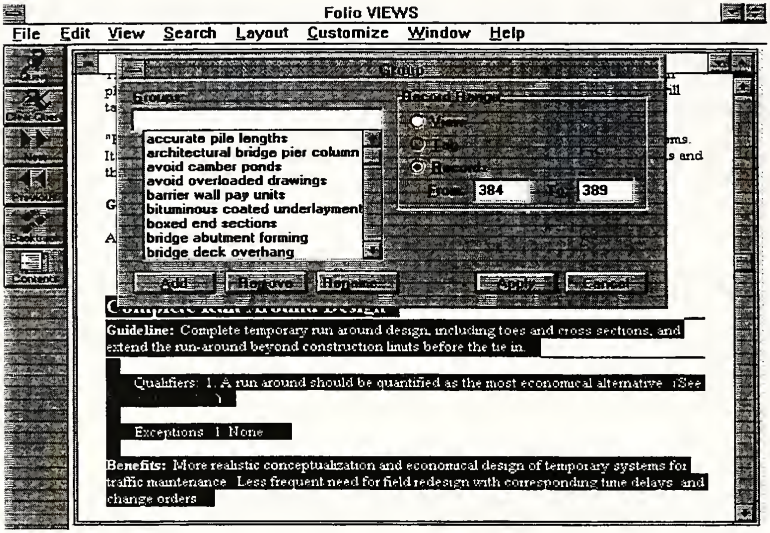


Figure 7 - Grouping a Lesson Inside Folio

Appendix B

CD Install Program

CD Installation Instructions

The install program on the CD-ROM was created using the software PC-Install. It creates an executable file named Cdsetup.exe. For a new installation the user runs the file Cdsetup.exe and the tool is installed on the PC. There is a option to uninstall the program.

The installation program does the following. It creates a directory named Indotcon and copies files into it. It copies some system and ClearVideo files into the Windows\System directory. It modifies the system.ini file and the indot.ini file. It creates a Windows group and icon and assigns the correct shortcut statement. The source code for the install program is shown below.

Cdsetup.exe - Source Code

```
WINITEM: "INDOT Constructability", "$SOURCEDRIVE$:\INDOT\indot.exe
/f=$sourcedrive$:\indot\indot.jdb", "INDOT Constructability", "$sourcedrive$:\indot\",
"$SOURCEDRIVE$:\INDOT\indot.ico"
WINITEM: "INDOT Constructability", "$defaultdir$\unstall", "Uninstall INDOT
Constructability"
TITLE: "INDOT Constructability Installation", 22, italic, bold
TITLECOLOR: cyan
SCREENGRAPHIC: "Orgback1.bmp", bottomright
SCREENCOLOR: blue, black
TITLECOLOR: white
FILE: "ORGBACK.000", popbmp="orgback", From="D:INDOT\Install\Orgback.bmp",
temp
UNINSTALL: YES
SHORTCUT: "$SOURCEDRIVE$:\INDOT\Indot.exe
/f=$sourcedrive$:\INDOT\indot.jdb", "INDOT Constructability"
DEFAULTDIR: "C:\Windows\System", noaskdrive, noaskdir
DIR2: "c:\Program Files\Iterated\ClearVideo Decompressor", noaskdrive, noaskdir
DIR3: "c:\INDOTCON", noaskdrive, noaskdir
FILE: "INDOT.000", From="D:\INDOT\Install\Indot.ldf"
FILE: "CTL3DV2.000", overwrite=new, From="F:\INSTALL\Ctl3dv2.dll"
FILE: "MSMASKED.000", overwrite=new,
From="C:\WINDOWS\SYSTEM\Msmasked.vbx"
```

FILE: "c:\INDOTCON\BVIEWS.000", source="bviews.000",
From="F:\INDOT\INSTALL\Bviews.exe"
FILE: "c:\INDOTCON\CUSTOM.000", source="custom",
From="F:\INDOT\Custom.dct"
FILE: "c:\INDOTCON\Indot.ini", source="Indot.000", From="F:\INDOT\INDOT.ini"
FILE: "c:\INDOTCON\FEWIN386.000", source="fewin386.000",
From="F:\INDOT\INSTALL\Fewin386.dll"
FILE: "c:\INDOTCON\FOLIOBMP.000", source="foliobmp.000",
From="F:\INDOT\INSTALL\Foliobmp.dll"
FILE: "c:\INDOTCON\FOLIOWMF.000", source="foliowmf",
From="F:\INDOT\INSTALL\Foliowmf.dll"
FILE: "c:\INDOTCON\VIEWS.000", source="views.000", From="F:\INDOT\Views.ini"
FILE: "C:\INDOTCON\THREED.000", source="Threed.000",
From="F:\INDOT\Threed.vbx"
FILE: "C:\INDOTCON\CMDIALOG.000", source="Cmdialog.000",
From="F:\INDOT\Cmdialog.vbx"
FILE: "C:\INDOTCON\BROWSER.000", source="browser.000",
From="F:\INDOT\Browser.exe"
INIFILE: "DRIVERS32", "VIDC.UCOD", "CLRVIDDD.DLL",
"C:\Windows\system.ini", add
INIFILE: "indot", "working", "$sourcedrive$:", "C:\indotcon\indot.ini"
FILE: "C:\Program Files\Iterated\ClearVideo Decompressor\CVREADME.000",
source="cvreadme.000", From="C:\Program Files\Iterated\ClearVideo
Decompressor\cvreadme.txt"
FILE: "C:\Program Files\Iterated\ClearVideo Decompressor\LICENSE.000",
source="license.000", From="C:\Program Files\Iterated\ClearVideo
Decompressor\License.txt"
FILE: "CLRVIDDC.000", overwrite=new,
From="C:\WINDOWS\SYSTEM\clrviddc.dll"
FILE: "CLRVIDDD.000", overwrite=new,
From="C:\WINDOWS\SYSTEM\clrviddd.dll"
FILE: "CLRVIDQT.000", overwrite=new,
From="C:\WINDOWS\SYSTEM\clrvidqt.qtc"
FILE: "CLRVIDTD.000", overwrite=new,
From="C:\WINDOWS\SYSTEM\Clrvidtd.tpd"
FILE: "CLRVIDTI.000", overwrite=new, From="C:\WINDOWS\SYSTEM\Clrvidti.tpd"
FILE: "CLRVIDTL.000", overwrite=new,
From="C:\WINDOWS\SYSTEM\Clrvidtl.tpd"
FILE: "INDOT.ico", From="F:\INDOT\Indot.ico"
DIR4: "c:\temp", noaskdrive, noaskdir

Appendix C

User Manual

User Manual

Installation

The program is installed by running the program Cdsetup.exe located on the CD-ROM. From Run type the CD Drive letter:\Cdsetup. For example if the CD drive is D then the user will type in D:\Cdsetup. This will start the install program and add the application to the PC.

Startup

The application is started by double clicking the INDOT Constructability icon within the INDOT Constructability group. Figure 1 shows the icon and Group setup for Windows 95 and Figure 2 shows the setup for the Windows 3.x operating environment.

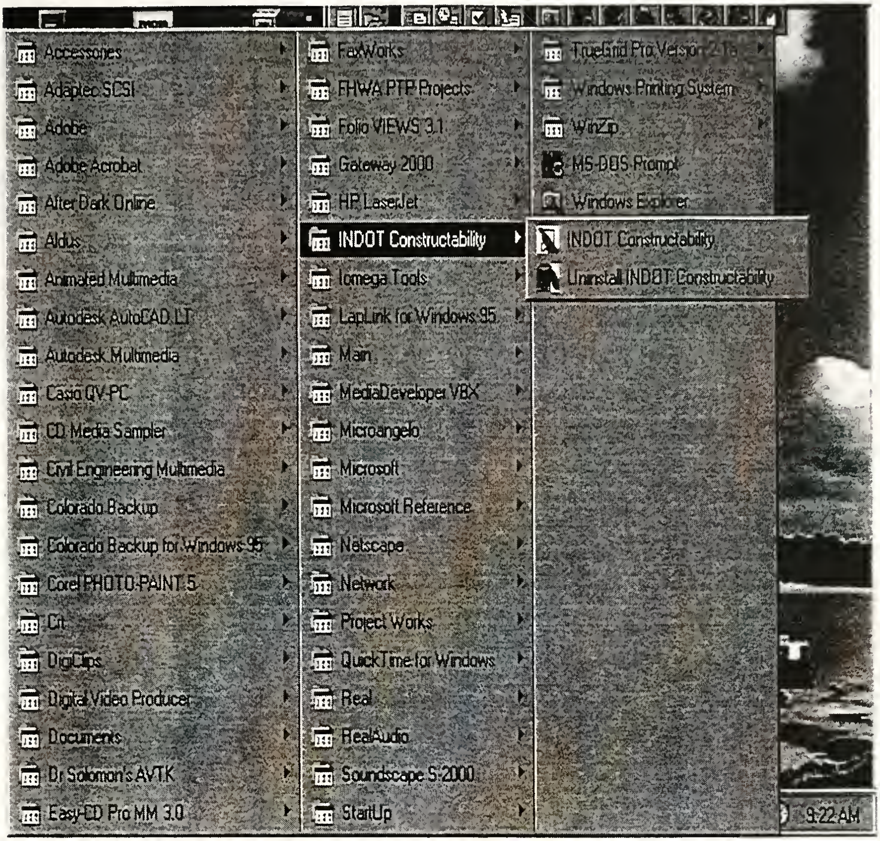


Figure 1 - Windows 95 Screen

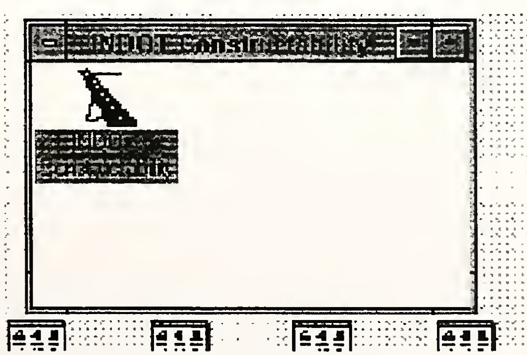


Figure 2 - Windows 3.x Screen

Double clicking the icon will launch the application by first loading the "Information Base" through Folio Views and then opening the initial screen shown in Figure 3.

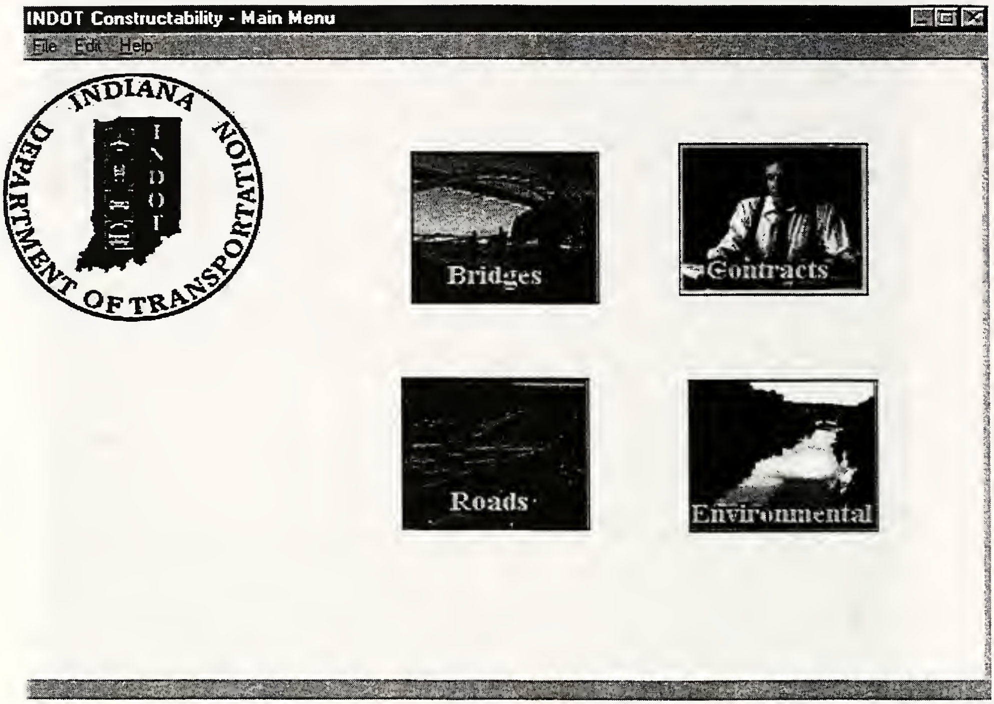


Figure 3 - INDOT Constructability Main Menu Screen

On this screen the user has four options or categories to choose from: Bridges, Contracts, Environmental, and Roads. The 63 lessons are grouped into these four. The user selects a category by clicking on its icon. This opens a new screen which is referred to as a category screen. Figure 4 is the one for Bridges.

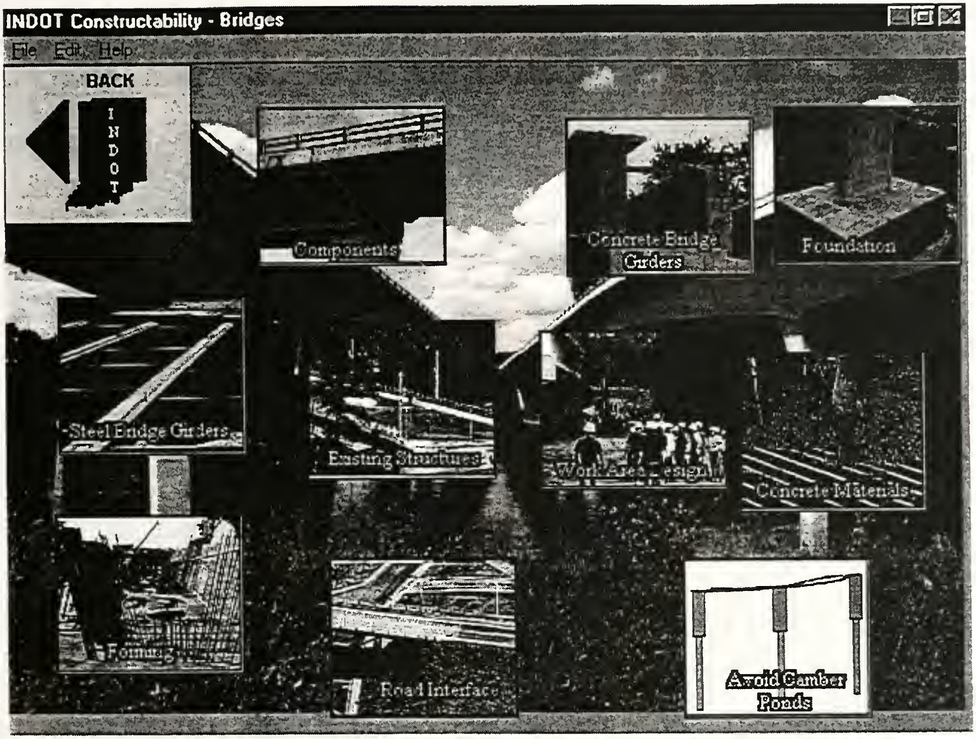


Figure 4 - Bridge Category Screen

This level screen contains icons representing another level, called a detail level, or a lesson learned. For example, in the above screen, clicking the Forming icon opens the detail level screen shown in Figure 5. If the icon is a Lesson then a search process is activated and the lesson is displayed to the screen. One is shown in Figure 6.

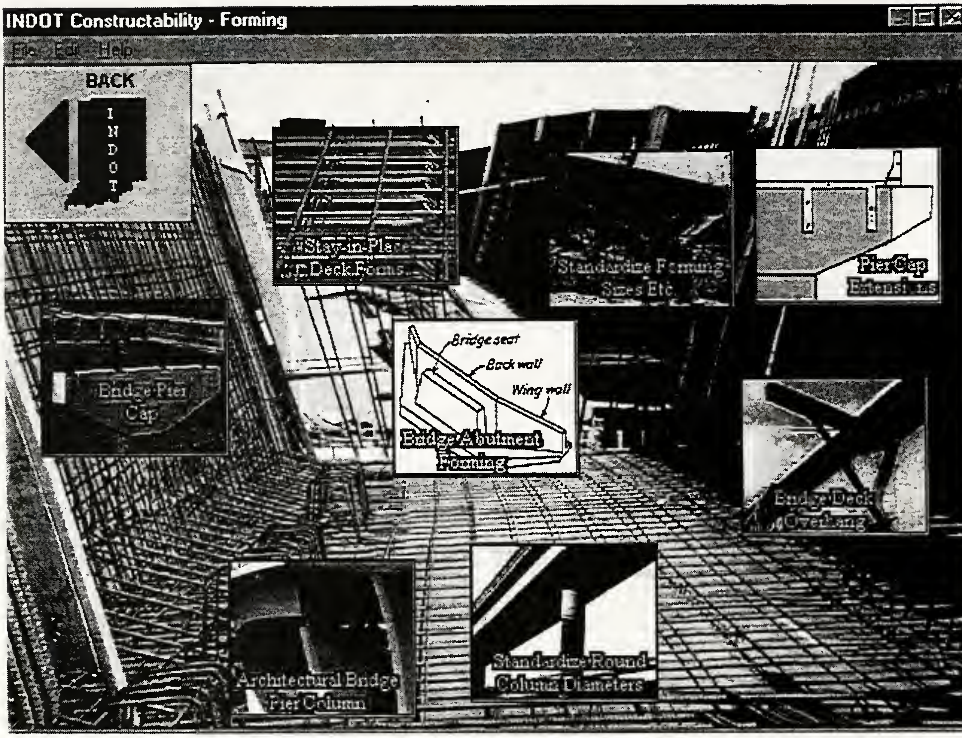


Figure 5 - Forming Detail Level Screen

Icons located at this level represent an actual "Lesson Learned". Clicking a Lesson icon will start a search process that opens the Information Base, retrieves the lesson , and displays it on the screen. Figure 6 shows the Lesson "Bridge Pier Cap."

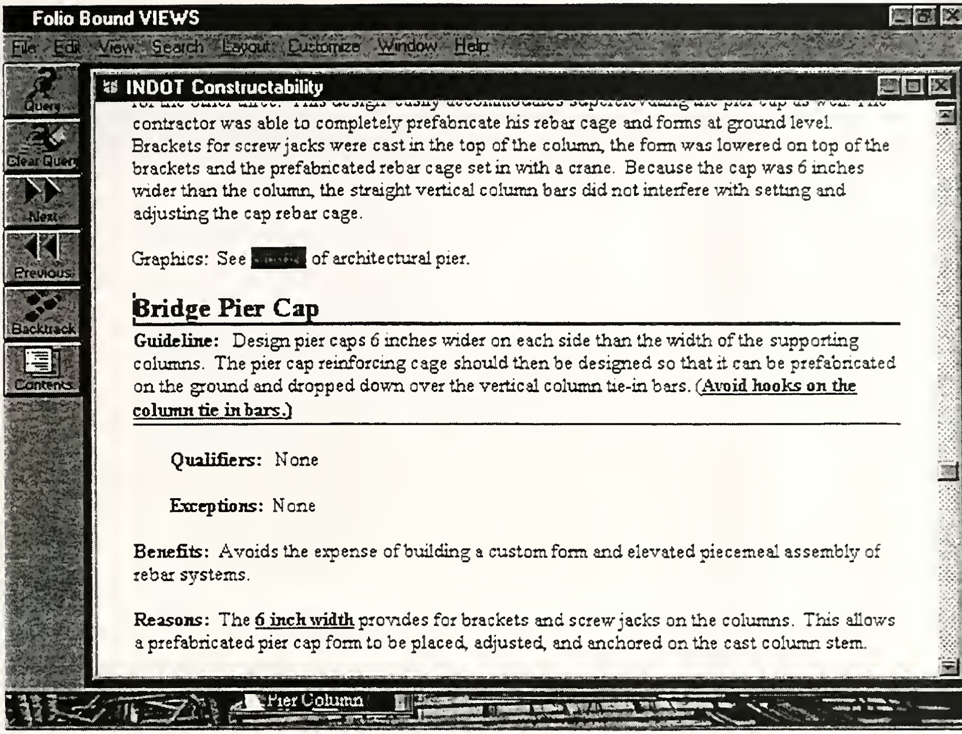


Figure 6 - Bridge Pier Cap Lesson

Multimedia Features

In most of the lessons multimedia is used to enhance and describe the lesson. Where appropriate, pictures, figures, design details and sections, sound clips, or movie clips are either embedded or hyperlinked. Hyperlinks are represented by colored text and the cursor will change to a pointing hand. Other information such as related specifications, design tables, and design memorandums have been hyperlinked. Figures 7 - 12 illustrate some of the possible information sources available through hyperlinks. The color scheme used in the hyperlinks is the following:

Blue - Figures
Orange - Pictures
Green - Other lessons or popups
Red - Quotation
Purple - References
Brown - Specifications
Yellow box - Audio
Dark Red box - Video

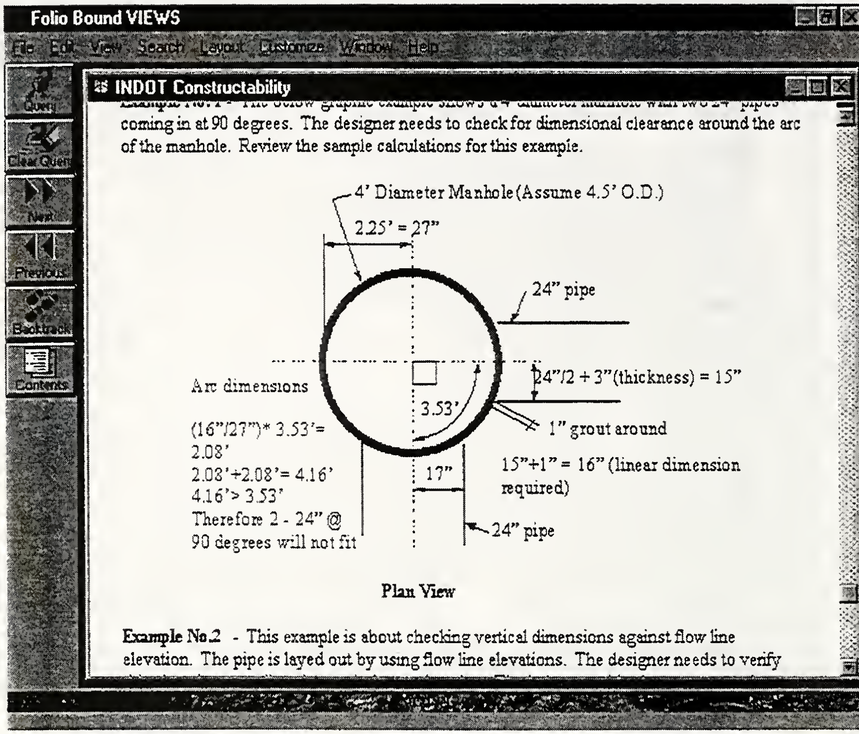


Figure 7 - Embedded Graphics

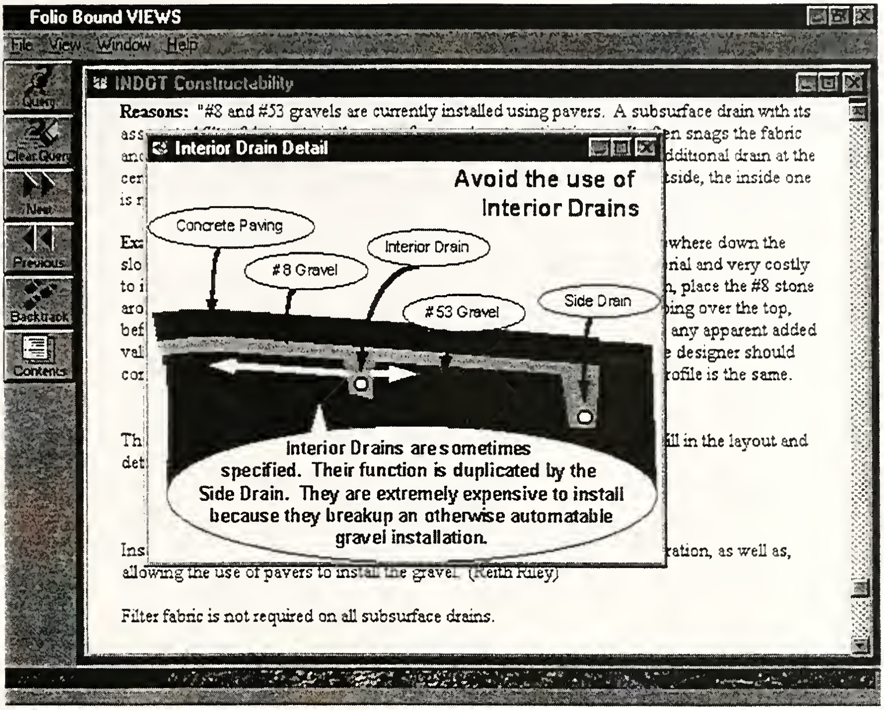


Figure 8 - Pop-up Graphics

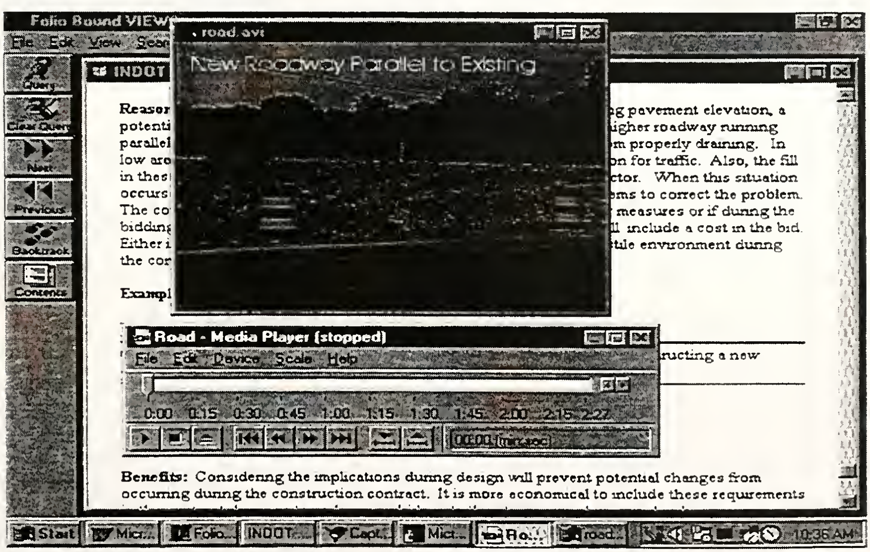


Figure 9 - Video and Sound Clips

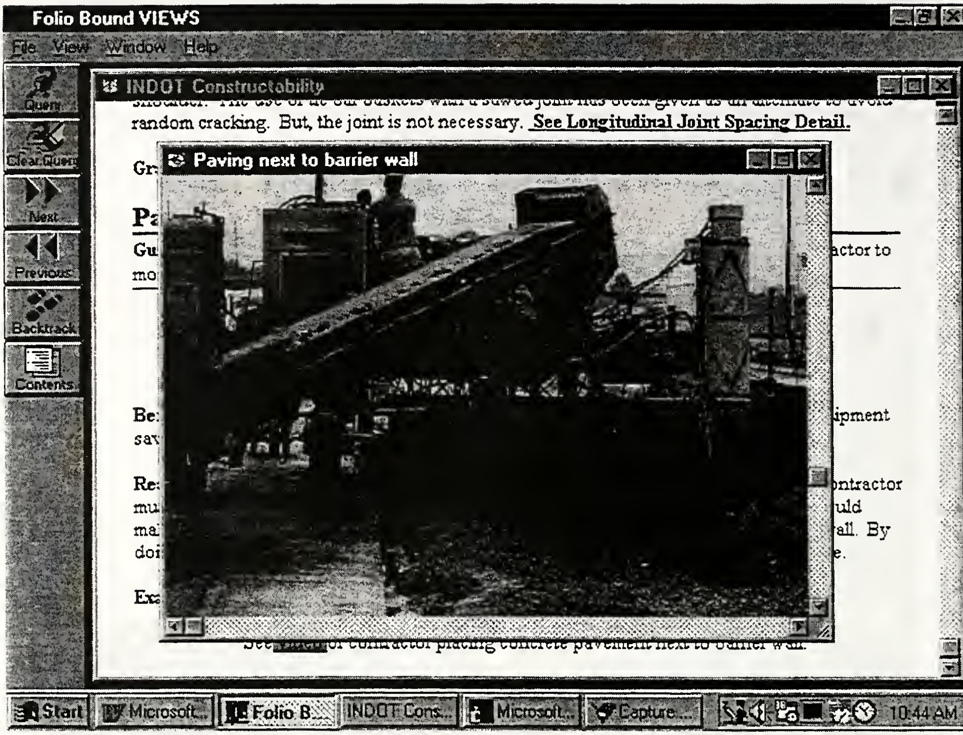
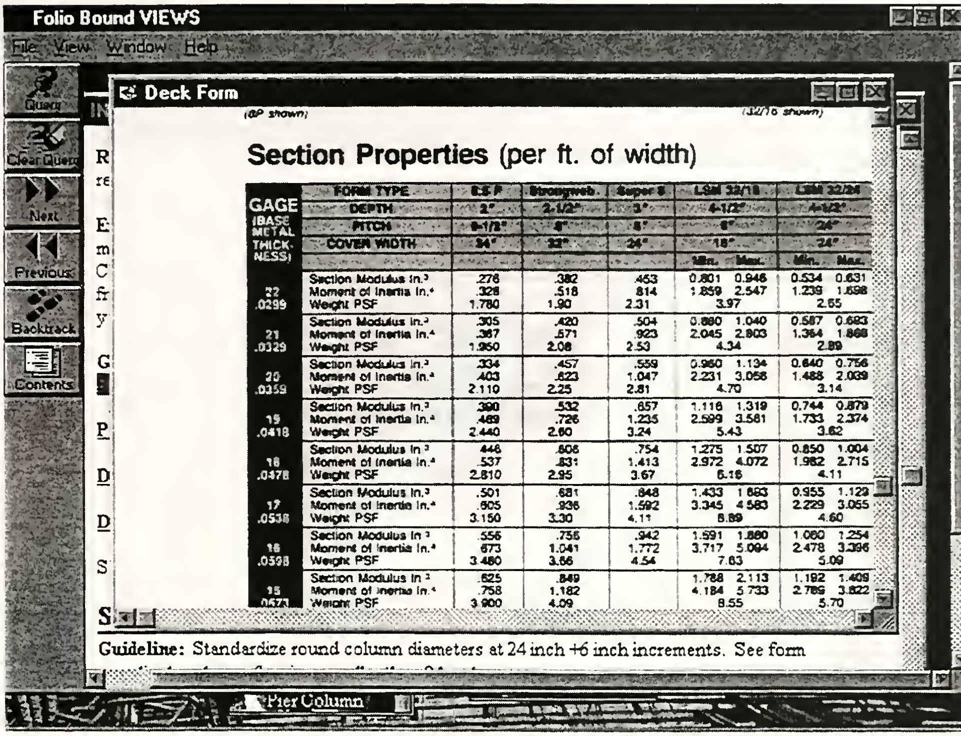


Figure 10 - Pop-up Pictures



Section Properties (per ft. of width)

GAGE (BASE METAL THICKNESS)	FORM TYPE	[illegible]	Strongweb.	[illegible]	LSM 32/18		LSM 32/24	
	DEPTH	2"	2-1/2"	3"	4-1/2"		4-1/2"	
	PITCH	[illegible]	[illegible]	[illegible]	[illegible]		24"	
	COVER WIDTH	24"	32"	24"	18"		24"	
					Min.	Max.	Min.	Max.
22 .0299	Section Modulus In.^{3}	.278	.382	.453	0.801	0.946	0.534	0.631
	Moment of Inertia In.^{4}	.328	.518	.814	1.859	2.547	1.239	1.698
	Weight PSF	1.780	1.90	2.31	3.97		2.65	
21 .0329	Section Modulus In.^{3}	.305	.420	.504	0.880	1.040	0.587	0.693
	Moment of Inertia In.^{4}	.367	.571	.923	2.045	2.803	1.364	1.868
	Weight PSF	1.950	2.08	2.53	4.34		2.89	
20 .0359	Section Modulus In.^{3}	.334	.457	.559	0.960	1.134	0.640	0.756
	Moment of Inertia In.^{4}	.403	.623	1.047	2.231	3.058	1.488	2.039
	Weight PSF	2.110	2.25	2.81	4.70		3.14	
19 .0418	Section Modulus In.^{3}	.390	.532	.657	1.118	1.319	0.744	0.879
	Moment of Inertia In.^{4}	.469	.726	1.235	2.599	3.561	1.733	2.374
	Weight PSF	2.440	2.60	3.24	5.43		3.62	
18 .0478	Section Modulus In.^{3}	.446	.608	.754	1.275	1.507	0.850	1.004
	Moment of Inertia In.^{4}	.537	.831	1.413	2.972	4.072	1.982	2.715
	Weight PSF	2.810	2.95	3.67	6.16		4.11	
17 .0538	Section Modulus In.^{3}	.501	.681	.848	1.433	1.693	0.955	1.129
	Moment of Inertia In.^{4}	.605	.936	1.592	3.345	4.583	2.229	3.055
	Weight PSF	3.150	3.30	4.11	6.89		4.60	
16 .0598	Section Modulus In.^{3}	.556	.756	.942	1.591	1.880	1.060	1.254
	Moment of Inertia In.^{4}	.673	1.041	1.772	3.717	5.094	2.478	3.396
	Weight PSF	3.480	3.66	4.54	7.63		5.09	
15 .0673	Section Modulus In.^{3}	.625	.849		1.788	2.113	1.192	1.409
	Moment of Inertia In.^{4}	.758	1.182		4.184	5.733	2.789	3.822
	Weight PSF	3.900	4.09		8.55		5.70	

Figure 11 - Hyperlinks to Design Information

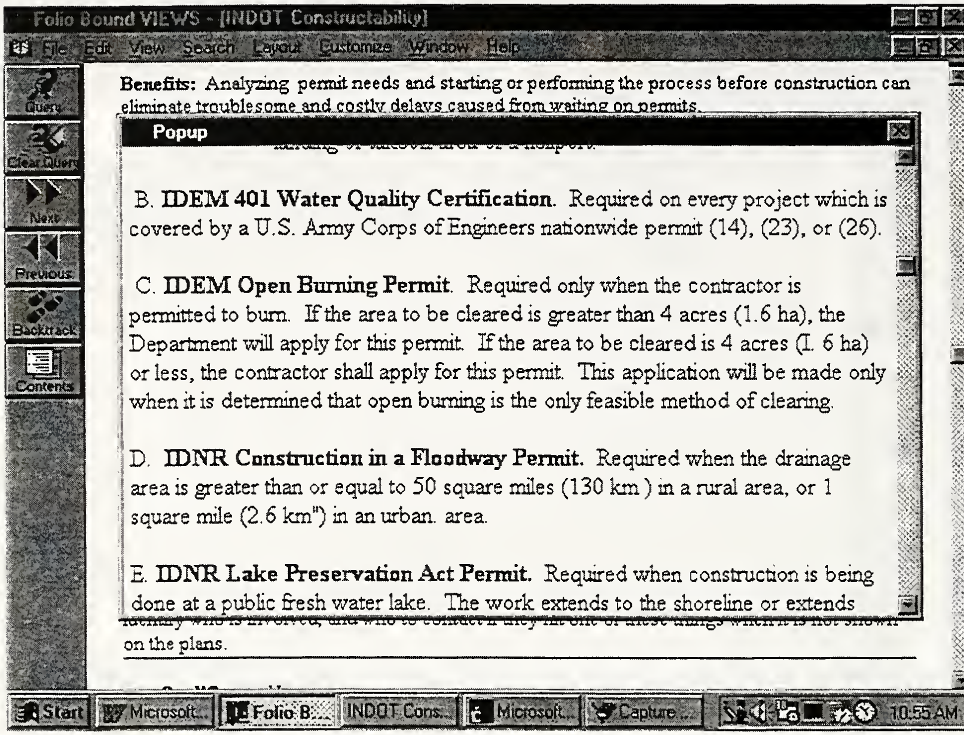
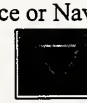


Figure 12 - Hyperlinks to Pop-up Design Memos and Specifications

Minimize Button

The Windows operating environment provides this button to place an application or window in stand-by or lost focus mode. This button is located in the upper right-hand section of the screen. This button is used to go from the Lesson Learn screen back to the User Interface or Navigation screen. The below symbols are the minimize buttons used in Windows 3.x  and Windows 95 .

When a Lesson Learn icon is selected, Folio Views is launched and the desired lesson is retrieved to the screen. After the lesson has been reviewed the user returns to the navigation by clicking the upper right Minimize button. See Figure 13 below.

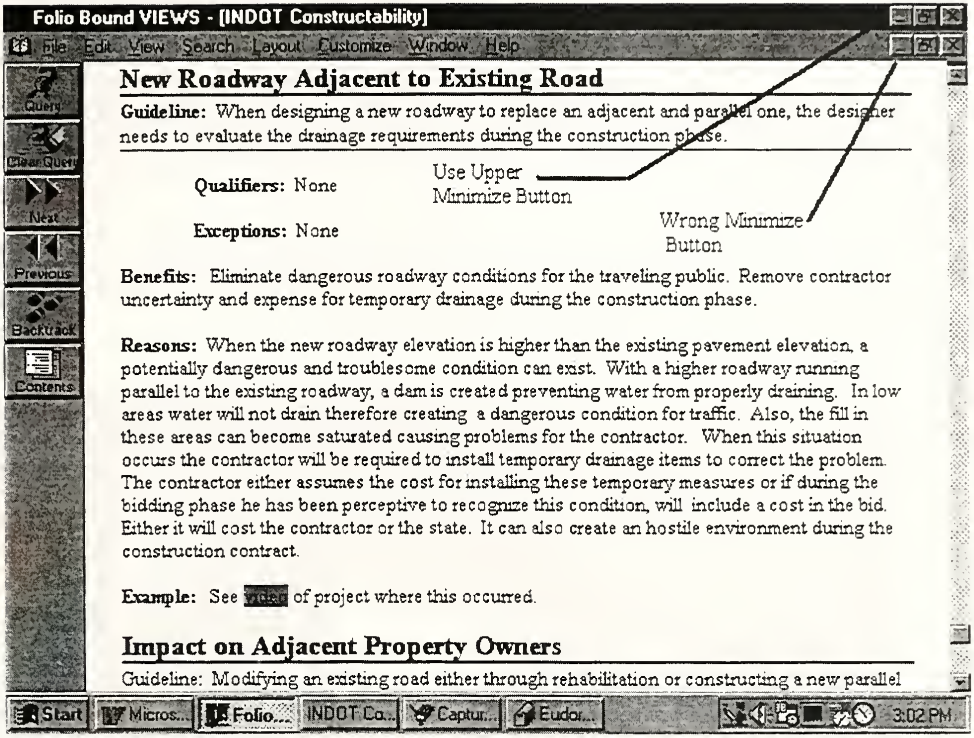


Figure 13 - Minimize Button

User Instructions

Only the mouse is required when searching and retrieving the information. No commands or keyboard utilization is necessary. If the user wants to query the Lesson Information Base then the keyboard is required to enter the search string.

Bound Folio Views

The Lessons are stored in Bound Folio Views, an electronic informationbase. When a lesson is accessed the user will notice a screen change to one with lesson information and a menu and tool bar. These two bars give the user access to an assortment of Folio commands. Since the application is running off a CD(read only, no write) most of these are inoperable. Two features are useable and they are very helpful. One is the Query option. Query can search and locate in the informationbase occurrences of a text string. For example, if the user could find all instances of "Piles." The other feature is the **Table of Contents(TOC)** or **Contents.** This feature displays the lesson names and their groupings. The lessons are grouped according to the INDOT Specification hierarchy. From the TOC the user can double click the name and go straight to the lesson. Also the TOC can be expanded or shrunk.

BACK

The user navigates forward by clicking icons. To return to previous screens the user clicks on the icon in the upper left part of the screen. It is the icon with the left arrow symbol next to the Indiana state map.

Exit

The only way to exit the appiication is to go to a navigation screen(the one with icons) click on File and then in the dropdown box click the Exit command. This will save the changes. Exit without saving does not. This is shown in Figure 14 below.

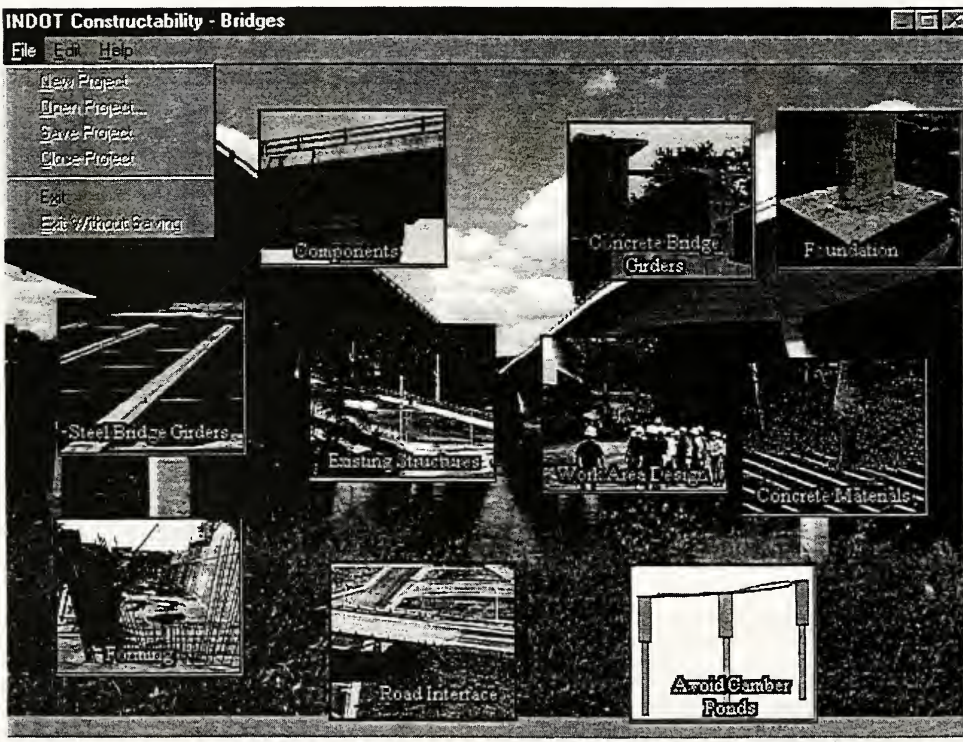


Figure 14 - Exiting the Application

CD Files

Files on a CD cannot be updated. Therefore, the informationbase cannot be revised in anyway. Also, a security feature prevents the informationbase from being copied to a hard drive and used.

Copyright

The material contained in the Informationbase is protected with a copyright as well as the program. Any duplication or modification is strictly prohibited.

Appendix D

Constructability Lessons

General Provisions

Plans Section

Avoid Overloaded Drawings

Guideline: Spread information over multiple pages in the plans rather than overlaying too much on one drawing.

Qualifiers: None
Exceptions: None

Benefits: More accurate bidding and fewer construction errors, and hence lower net cost.

Reasons: Designers often overlay too much information on the drawings. This is causing confusion in reading and difficulty interpreting the plans, especially when they are reduced to half size (which is really 1/4 size by area). Creating doubt or uncertainty in the interpretation or intent of the plans increases the probability of making mistakes during bidding and construction. Plans that are clear and uncluttered increase a contractors confidence during bidding and reduce the need for contingencies. (Walsh Construction / others)

Examples: One solution is to spread the information over multiple pages. For example, one drawing for utilities, one drawing for topographic, one drawing for structures, etc.

Graphics: See example of overloaded drawing.

Reanalyze Archived Plans

Guideline: Designs older than 1 year must be seriously reanalyzed for interim changes that may of occurred since the design was completed. Make sure pay items include all items required for construction. (Switzer & Huckleberry 1993)

Qualifiers: None
Exceptions: None

Benefits: Reduced errors, omissions, and need for field redesign. With resulting reduction in contract cost, change orders, contractor overhead, INDOT overhead, and time for construction due to changes in the interim.

Reasons: It is not unusual for projects to be designed and then, due primarily to budget restrictions, be archived for 1 to 10 years or more. (Switzer & Huckleberry 1993) Contractors and INDOT district personnel report little effort to update old designs prior to bidding.

Example #1: "Piling was going through 26 fiber optic cables from Indiana Bell. As a result, the structure had to be built around a steel box containing those cables. The additional cost was about $250,000 to build around the cables. After the fact, Indiana Bell estimated the cost to move the cables would have been only about $150,000. The design did not consider the steel box which had been added during the 10 years since the design. This error was discovered immediately, and involved so many people, that nobody could make a decision. It was on the critical path and severely impacted the job. After this redesign, the engineer discovered that the centerline was off 2 and 1/2 feet. So, back into redesign. This sort of thing happens when a set of plans has been on the shelf for a long time, and is not seriously reanalyzed for interim changes since the design." (Shutt 1993)

Example #2: " Sometime before a bid, an archived drawing needs to be reviewed by looking through the contract items and conducting a site inspection to make sure that everything still makes sense; probably by someone with some construction knowledge. Often there will have been changes; buildings added in this area or that, which don't show up on the plans. The designer must then determine how to get people in and out of the added buildings when the road is torn up. There may be no driveway according to the plans. When not addressed in design, it creates a problem between the state inspector and the contractor because of the time pressures present during a project." (Gross 1993)

Example #3: " A lot of times in field check procedures, designers do not compare their plans with actual field conditions. Sometimes a designer comes out and looks at the job and goes back and designs it and never comes back to compare the design with field conditions. Jobs have been put out for bid that have items missing, there are work items shown in the plans for which there are no pay items set up. For example, on a simple resurface job a curb was removed, but there was no pay item to put the curb back. A review of the proposal would reveal that the curb is being removed, but no pay item to put any curb back." (Gross 1993)

Example # 4 : " Projects designed 5 to 10 years ago and archived needs a complete evaluation. Standard specifications and project site conditions have probably changed. Physical site changes will significantly affect the scope of the project. The contract documents need to be reviewed in these two areas. " (Gross 1993)

Graphics: View a graphic showing the impact of changes on an archived drawing set.

Combined Projects

Guideline: Combining projects into one for letting and bidding.

Qualifiers: Every project that is a combination of other projects.
Exceptions: None

Benefits: Avoids overlap in bid items, and alignment differences from one job to the other. Provides for uniform specifications, cross sections and traffic control plans.

Reasons: When 2 or more projects are combined (bid together, and/or performed simultaneously), a new design condition is imposed requiring a coordinating redesign of the combined project.

Example #1: "When projects come together and uncoordinated traffic control systems overlap, it causes a major confusion to the traveling public. On a highway 40 project this happened and the traffic control had to be redesigned after the bid." (Shutt 1993)

Example #2: "Two projects were put together under one contract. Each was designed by a different designer/consultant and a coordinated design was never done before the bid. There was overlap in bid items. The alignment was different at the transition from one job to the other. They had different specifications and different cross sections, the jobs were almost unrelated, they were adjoining though. Although one was designed years before, they were put together with no check for the consequences. There was no coordinated traffic control plan, they had been designed completely independent and could not be worked that way." (Gross 1993)

Example #3: " On state highway 25 in Lafayette, there were separate designs for bridge, road, and signalization. The 3 projects were combined. Errors included: typical sections on the bridge plan had a different elevation from the road plan. The bridge design assumed the road work was completed. When run together, the bridge traffic plan had traffic running into a non existent road area. Temporary sheeting had to be installed for traffic diversion." (Switzer & Huckleberry 1993)

Graphics: None

Field Verify Existing Structures

Guideline: Designers should use old as-built drawings if possible, and redline all dimensions which are critical to their upgrade or removal.

Qualifiers: 1. Projects in urban areas are more likely to experience this type of problem.
Exceptions: None

Benefits: Lower net time and cost for construction through more accurate designs. Often sufficient time to field measure and correct design deficiencies is not available for the contractor. Steel and/or precast elements

Reasons: The most economical alternatives cannot be considered if inaccurate or incomplete information is used in design.

Examples: " When existing structures are rehabilitated, as-builts rather than old plans should be used to understand the correct existing elevation of the beams for instance. On a Reith Riley project, the old bridge elevations were not verified and turned out to be incorrect. As a consequence the bridge deck thickness could not be maintained and

still meet the elevation of the approach paving or achieve the new super-elevations designed throughout the bridge structure." (Reith Riley)

Graphics: None

Notes on Drawings

Guideline: Place all the notes in one place, eliminating stray notes. And describe them fully in the special provisions.

Qualifiers: None

Exceptions: None

Benefits: This makes bidding more accurate. (Reith Riley)

Reasons: This is one of INDOT Contractors most prevalent requests.

Examples: None

Graphics: See sample notes on drawing.

Dimensions on Drawings

Guideline: Put individual, overall, and especially slope dimensions prolifically throughout drawings, not in just one place. Make sure all letters and numerals are legible when reduced to half size.

Qualifiers: None
Exceptions: None

Benefits: Increases contractor understanding of designer intent.

Reasons: Design drawings are often used by field personnel without engineering training. If dimensions are not available, it increases the level of engineering training required to understand and derive them. When selecting character point size, remember when a drawing is reduced to half size, which will be used in the field, point sizes and all other items are actually reduced to 1/4th their original size. (A 32-point character becomes an 8-point, etc.)

Examples: None

Graphics: See 'Half Size' Reduction Chart showing the visual effect of reduction'.

Skewed End Bent Views

Guideline: One view of an end bent provided on a skew should not be specified as typical-rotated-180-degrees for the other end. Provide the rotated view as well. (Reith Riley)

Qualifiers: None
Exceptions: None

Benefits: Increase construction productivity and accuracy.

Reasons: To do otherwise results in much confusion.

Examples: The figure below shows a plan view of a skewed bent. The plan view says rotate 180 degrees for the other bent. This causes confusion for the contractor to lay it out with this type of information. It would save the contractors time and money if the designer drew the actual view of the other bent.

Graphics: See Figure with one plan view .

See Figures for two plan views.

End Bent No.1
End Bent No.4

Bidding Requirements and Conditions

Setting Bid Periods

Guideline: Provide 4 weeks for contractors to bid major dirt jobs (> 500,000 CY). Most addendum require a week for the contractor to accommodate. Addendum requiring contractor arrangements for off site borrow or fill require 2 weeks.

Qualifiers: None

Exceptions: None

Benefits: Reduced contractor uncertainty at the time of the bid with its associated reduction in contingency.

Reasons: Major dirt jobs > 500,000 CY. need 4 weeks to bid. Addendum which include major scope changes, need more than a few days to accommodate. Most addendum require a week for the contractor to accommodate. (Reith Riley)

Examples: For example, from the statement that all borrow is available on jobsite, to one requiring the contractor to make arrangements for borrow off site, is a very time-consuming change. Often contractors will spend considerable time at consultants and INDOT offices to obtain advance notice of upcoming jobs to enable economical off-site borrow, waste and other right of way arrangements to be made.

Graphics: None

Work Area Design

Increase Work Zone Size

Guideline: Use crossovers and increase work zone length limits to 10 miles or longer.

Qualifiers: 1. That it is indeed a fallacy that if you limit the contractor work zone to 2-3 miles, traffic will move quicker. Because after traffic is down to one lane, length makes very little difference in the time it takes to move through the work area.

Exceptions: 1. Switzer & Huckleberry (1993) Confirmed the limit does exist, but did not fully agree with the notion that the only impact is at the neckdown. Their experience is that there is also some impact due to the length of the bypass.

Benefits: Increases construction quality and safety for both the contractor and the traveling public, and decreases cost and time for construction. On a single 10 mile reconstruction project totaling $6 million: save construction and removal of 3 crossovers at ~$50,000 ea., plus another 2-3% of the project (~$150,000) due to removal of phasing inefficiency.
Total savings ~$300,000 or ~5%, and 1 year instead of 1 & 1/2 years.

Reasons:

The current practice of limiting those work zones to 2 or 3 miles adds the expense of the additional crossovers and phasing. Where crossovers are built on 4 - lane roads and contractors are given one entire side of the road to work on, it has made it a lot safer for the contractors and it really hasn't impacted the traveling public that much because if they are going to be traveling through that work zone, they would be down to one lane anyway. Overall, it would be the best to allow the cross over, rather than force 1 lane rework at a time. The quality of work is better, and it costs a lot less. Especially on bridges, the time will be one third less.

Examples: Instead of one lane on the construction side, it creates one lane each way, both on one side of the road. This makes a much safer area to work for both the contractor and the traveling public. Most of the accidents occur in the funneling area, where you take it down from two lanes to one lane. Once you get them down to one lane, you really don't have a problem, they don't have anyplace else to go and they move along. The traffic jams and tie-ups occur at the merging areas. Crossovers have allowed the contractor to be a lot more efficient because they have an entire side of the road to work in and they don't have to worry about traffic.

Graphics: See picture of work zone.

Detail Phased Cross Sections

Guideline: Select construction limits using detailed plans and cross sections through each phase of the construction.

Qualifiers: 1. Check areas with high intensity construction such as bridges and temporary roads

Exceptions: 1. Right of way constriction problems generally only occur in urban areas. (Shutt 1993)

Benefits: Reduced time & cost for construction of bridges and temporary facilities.

Reasons: INDOT contractors have suggested that temporary facilities, (runaround roads and temporary bridges), are often designed too close to the permanent structures for cost-effective construction. When this occurs, it may require temporary shoring, re-excavation and other construction methods, which are much more expensive and time consuming. A temporary right-of-way extension is often sought by the contractor under these circumstances.

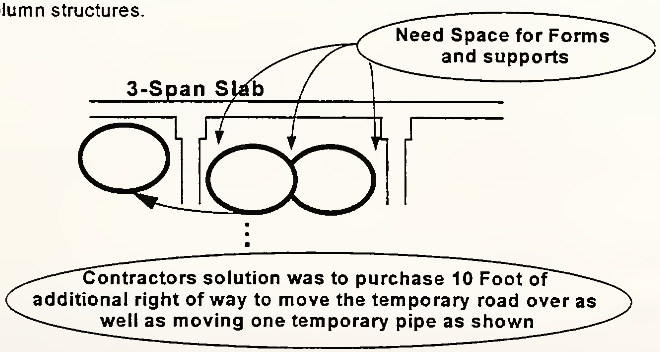
A contractor will pay anything up to the marginal cost of alternative means of constricted construction, to obtain these increased temporary limits. This marginal cost may far exceed the market value of temporary use of the additional property. Further, temporary access arrangements can take months or in the worst case be impossible to obtain. Requiring the contractor to make them during the bid can create an expensive level of uncertainty, and can be very disruptive to project scheduling.

Drawing cross sections through temporary, as well as permanent facilities, provide an effective method for the designer to consider the interaction between them; and perhaps justification for increased construction limits and right of way.

Example 1: Not buying right-of-way for construction can cause increase construction costs as well as long-term problems. "For example, on I-65 at a railroad under pass, we had to cut the slope at 1:1, and it is now almost impossible to hold."(Switzer & Huckleberry 1983)

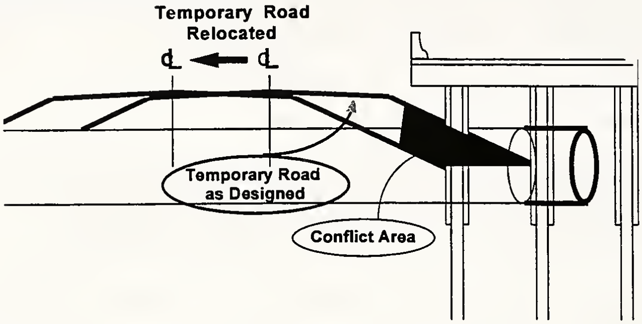
Example 2: A temporary run-around road was placed so close to construction that it infringed on the temporary drainage pipe.

A temporary by-pass road was designed so close to the permanent bridge structure that temporary pipes protruded under the new structure and conflicted with each other and the contractors need to form the slab and column structures.



Further, on this INDOT project the temporary bridge was designed so close to the structure that the toe of slope on the temporary dirt, and temporary road culverts run back underneath the new structure. Building according to the plans, would have required sheeting and shoring the temporary fill, and a 40-foot clear span form, in order to put in the new bridge encasements and cast the slab. The contractor bought a right of entry from the property owners and is moving the temporary over 10 feet. Often, as in this case, only the centerline of the temporary road was given. It is necessary to draw the whole temporary road with its shoulders and toe. Then, cross sections through the

temporary road and bridge structure would have clearly revealed this expensive conflict. That the road would be so close, for example, that a temporary barrier would be required to prevent debri on cars during the removal of the existing bridge. The design engineer admitted not realizing his design required either procedure. (See Graphic Below.) Due to the relocation, the temporary road conflicted with trees and a residence that were beyond the original construction limits. This all could have been avoided if the designer had taken the time to do cross sections along the proposed temporary road.



Q: Referring to contractor's drawings, Were any sections like this shown on the design?
A: No. There were no sections through the bridge. Sections were made on the approaches up to the end of the old bridge, but not on the bridge itself. In addition, it is often found that contours, and obstacles (trees, homes, utilities, etc.) beyond the constricted ROW are incorrect and incomplete, rendering redesign by the contractor very difficult and expensive, especially during the heat of a bid.

Example 3: " On highway 38, the design had 2 strips on the outside and 9-10 feet left in the middle zone to work in. It was a virtual impossibility for the contractor to work this way." (Switzer & Huckleberry 1983)

Example 4: " One job didn't have enough right-of-way to flair out the end of the guard rail. The guard rail ran up the road to the point the sides were large enough to terminate the guard rail and meet federal standards." (Switzer & Huckleberry 1983)

"On some past bridge projects, construction limits are at the Right-of-Way(R/W). It cannot be built without encroaching on the R/W. For example, plans show a slope of 3:1, but if you lay it out it will not fit within the R/W.

The designer needs to draw cross sections through each section of the structure, for each phase of the project. Then and only then can the designer adequately visualize what it will take to build the project during those phases. "

"Earth retention during phases is typically considered incidental and included in other items. It could be very substantial or even eliminated if the engineer would do the cross sections and think about it before the design. " (Beaty Construction Company)

Graphics: None

Also See Constructability Concepts
Provide 5 Ft ROW From Construction Limits
Clear Legal Access

Complete Run Around Design

Guideline: Complete temporary run around design, including toes and cross sections, and extend the run-around beyond construction limits before the tie in.

Qualifiers: 1. A run around should be quantified as the most economical alternative. (See **Work Area Size**.)

Exceptions: 1. None

Benefits: More realistic conceptualization and economical design of temporary systems for traffic maintenance. Less frequent need for field redesign with corresponding time delays and change orders.

Reasons: The design practice of identifying only the centerline of a temporary runaround often results in serious plan deficiencies. The extent of the slopes and toe, and their interaction with utilities (existing, temporary and new), and with areas required to build the new facilities; are difficult to design without the aid of cross sections.

Examples: Forcing cross sections through strategic areas and standards on runarounds would be the best way to control/design them for constructability. More frequent sections would be required than every even station. Runarounds are often long enough to build the structure, but not to make the tie ins.

"To shorten the project, designers will bring the temporary run around back in within the construction limits, and then put in the special provisions that you can't close the road. Well, we've often had to have a 20 day shut down just to make the tie-in, a problem which could have been avoided if this concept had been applied. If you're going to have a run around, make it far enough away that you can do your work." (Switzer & Huckleberry 1983)

Graphics: Typical plan view of a run-around.

See Standards Sheet for Runaround Geometry and Surface Quantities

See Standards Sheet for Runaround Signs

Consult with FHWA publication, Part VI Standards and Guides for Traffic Controls for Street and Highway Construction, Maintenance, Utility, and Incident Management Operations(Part VI of the Manual on Uniform Traffic Control Devices(MUTCD))

See MUTCD Runaround Detail

Removal of Existing Structures

Guideline: Identify the existence of and quantify the scope of very old existing structures. Once quantified, if all or some of the old structure must be removed, describe it and list its removal as separate bid item.

Qualifiers: 1. Projects in urban areas are more likely to experience these types of projects. Design engineers should make a thorough investigation to reduce this likelihood.

Exceptions: None

Benefits: Considering existing structures and their interference with new construction can possibly reduce construction cost and redesign during construction.

Reasons: Anytime uncertainty enters a bid item, such as class X unclassified foundation excavation, contractors elevate the unit price. It is more cost effective to perform the investigation and discovery of existing structures, particularly foundation, during design phase then the construction phase soils investigation work should include a discovery requirement. Obtaining this discovery information at design and including it in the contract documents, provides information to bidders removing uncertainty and lowering the unit price for the item. It allows the contractor to plan the work and eliminate work delays and change orders.

Examples: " A preexisting structure was not discovered during design. It was very costly to probe/dig around to discover what is there during construction, while other activities must be halted. If suspected, (and it should be suspected if it is in the corridor as shown on old drawings) it should be probed for and identified during the design." (Shutt 1993)

Graphics: None

Clear Legal Access

Guideline: Clear legal access to the right of way before the bid.

Qualifiers: None

Exceptions: Potential right-of-way problems should be described in the special provisions. Inform the contractor before bid date.

Benefits: Any information provided to the contractor before bidding will lessen the impact of project time and cost.

Reasons: The designer establishes the right-of-way requirements, and then the right-of-way department purchases

the property. When unknown right-of-way clearance problems exist, it creates adversarial relations right off between the property owners, the project manager, area engineer, & the contractor. A large change order is a typical outcome. The designer should verify right-of-way clearances or problems before bid date.

Examples: On SR 38 project in Lafayette, 2 parcels did not have clear right-of-way. A major reason for this was the lack of cooperation between state, county, and city over right-of-way purchases. The project was let in May, the contractor started in June, and on one parcel, right of entry was not granted until December. This held up relocating water, sewer, gas, and telephone utilities. This severely impacted the project schedule and resulted in additional changes by the contractor.

Graphics: None

Also See Constructability Concepts
Provide 5' ROW From Construction Limits
Detail Phased Cross Sections

Rail Road Approval Before Bid

Guideline: Designer needs to get any required railroad approvals prior to the bid instead of contractor.

Benefits: Avoids cost additions due to railroad changes and/or time delays resulting from railroad approval processing time.

Reasons: Railroad requires approval of anything constructed on their ROW. For example, new bridge beams. This process is time consuming and should be accomplished as part of the design.

Provide 5' ROW From Construction Limits

Guideline: Provide a 5-ft minimum right of way beyond construction limits.

Qualifiers:
1. On all areas with slopes (+ or -)
2. Or high intensity construction such as bridges and temporary roads

Exceptions:
1. Where no slope, grading or construction passage is required at or beyond the construction limit
2. Right-of-way constriction problems generally only occur in urban areas. (Shutt 1993)

Benefits: Reduced cost for construction of bridges and temporary facilities.

Reasons: INDOT contractors have suggested that the construction limits are often designed too close to the right-of-way limits, especially in intense construction areas. This, when it occurs, requires them to do work which cannot be performed without encroachment (going beyond the right-of-way).

The state, by virtue of its right of eminent domain, can purchase land or right of ways at defendable market prices. The current practice of designing construction to be performed at less than 5 feet (usually 0 to 5 feet from the right of way), often requires the contractor to make some sort of deal with adjacent property owners. (See plan graphic.) A contractor will pay anything up to the marginal cost of alternative means of constricted construction, in order to obtain increased temporary limits. This marginal cost may far exceed the market value of temporary use of the additional property. Further, temporary access arrangements can take months or in the worst case be impossible to obtain. Requiring the contractor to make them during the bid can create an expensive level of uncertainty, and can be very disruptive to project scheduling.

When utilities are to be relocated to the area between the right of way and the construction limits, there should be at least 10 feet between them, or the contractor or utility company will have to make a deal with the property owner.

Examples:

If one is cutting a slope or a ditch, the job cannot be done if the construction limits are identical to the right of way limits.
This condition requires either one track on top at the start, or the spoil will come up and require gradually working it back.

The same thing will happen on a fill. The material can be laid in, but it is still going to spill down the slope. And at the end of the job, one must dress it by pushing it back up. A Right of Way at the toe of the slope, does not allow

any room to work.

The Right of Way should be shown on the cross sections with both the temporary road and the new facilities. Then one can see if a problem exists. Refer to drawing bottom of previous page. (Listen to audio description.) while viewing the above graphics.

Graphics: None

RIGHT OF WAY RESTRICTIONS Most roadway rehabilitation projects have limited ROW. When it is not politically or economically feasible to obtain additional ROW, the project must be designed to insure adequate area for construction equipment, as well as proposed construction items. Again, if the plans do not consider encroachment or other conflicts with existing ROW limits, field challenges will be made to alleviate them and the changes *may* not be in the best interest of the project.

The problems with ROW constraints are often more subtle than with utilities. There is no doubt when an existing utility line is hit, but there are many variables for ROW constraints. An existing fence on private property may restrict the swing of a backhoe or in other ways limit the maneuverability of excavating equipment. An existing tree on private property, but near the ROW, has roots that can conflict with proposed excavation.

An example of ROW constraints not properly considered:

A proposed storm sewer system was designed to be at 30 feet to center line in a 33-foot ROW. Usually, there was a thick buffer of trees along the ROW and, often, there were fences at the ROW line. To excavate the trench, the contractor had to operate his equipment at an angle to the trench, thus slowing operations. This tight working condition was reflected in his bid. To reduce conflicts as much as possible, the system was moved away from the ROW as far as possible.

Another project also experienced tight working conditions, described as follows:

A retaining wall was designed with the toe of the foundation at 29.5 feet in a 30-foot ROW, with no easement for excavation or equipment. Fortunately, a field decision was made to eliminate the wall, so a solution for constructing it was not required. It is probable that encroachment would have been the only solution without waiting until an easement could be obtained.

As with other conflicts, ROW constraints must be eliminated in the design of the project so they do not have to be eliminated during construction.

Also, See Constructability Concepts

Clear Legal Access
Detail Phased Cross sections

Traffic Control

Center Lane Closure

Guideline: Seek another alternative to a work envelope with traffic flowing on both sides.

Qualifiers: None
Exceptions: None

Benefits: Center lane closures are so dangerous and expensive that they can be characterized as nonconstructable.

Reasons: With a center-lane closure there is no way in or out for the material and equipment deliveries, (because there is traffic on either side). After the barrier walls are set around a center lane on such a project, the middle lane access was restricted to 150', so at the end there was 150' to get trucks backed up, turned around, and merged into traffic. Also, the excavator would have been swinging around and overhanging into traffic lanes.

Examples: Such a traffic plan looked like it would work on paper but there was a much better way to go about it. Maintenance of traffic which was designed for 4 to 5 different phases, was redesigned by the contractor to be done in only two phases. Ten foot shoulders were widened to 12' which produced enough room to constrict the inside lane where crossover was possible. This eliminated 2 phases and the center-lane closure.

Graphics: Consult with FHWA publication, Part VI Standards and Guides for Traffic Controls for Street and Highway Construction, Maintenance, Utility, and Incident Management Operations(Part VI of the Manual on Uniform Traffic Control Devices(MUTCD))

Detail on Interior lane closure on multilane street.

Detail on Interior lane closure on freeway.

Traffic Control Plans

Guideline: A well conceived and documented traffic control plan should be a standard requirement of every design. It should include cross sections through temporary conditions and facilities.

Qualifiers: None
Exceptions: None

Benefits: Reduced confusion and increased safety to the traveling public as well as lower contract time, cost and increased safety for the contractor.

Reasons: Designers are currently forced to put a traffic control plan in the design, but the quality of such plans should be improved. (Switzer & Huckleberry 1983) Traffic control is one of the bigger issues that design people have a problem understanding if they don't have a lot of field experience. (Gross 1993) It was observed that frequent and judiciously located cross sections through temporary conditions and facilities (including utilities) could help the designers avoid some of the problems with traffic control.

Through experience, many contractors have developed considerable expertise in this area. Although a design is necessary to establish required level of service and other design parameters, considerable flexibility should be maintained by the department to encourage contractor redesign; which frequently results in significant benefit for all.

Examples: A new bridge on State Road 41 was built to replace an existing one. Close to the bridge SR 55 intersects SR 41. The new bridge is 15 to 20 inches higher. The contract required a rebuilding of the 16-inch deep bituminous approach. Because of the grade differential this was not possible. This required a week closure and working 24 hours to rebuild. Had cross sections been drawn through the approaches, this would have revealed the problem and design changes made to prevent this cost and inconvenience from occurring.

Graphics: Consult with FHWA publication, Part VI Standards and Guides for Traffic Controls for Street and Highway Construction, Maintenance, Utility, and Incident Management Operations(Part VI of the Manual on Uniform Traffic Control Devices(MUTCD))

See Detail for Component parts of Traffic Control.

See Detail for Tapers and Buffer Space Requirements.

Night Watchman

Guideline: Alternatives to this very expensive provision should be considered. If a watchman is necessary, state specifically in the special provisions that a night watchman will be required, and during what times, days, and seasons. Provide a bid item to accommodate any changes. (Contractors United)

Qualifiers: 1. A night watchman is to change a light bulb in a traffic control device, or for when a car plows through a traffic control setup and wipes every thing out. But for such an event the police are routinely given contractor superintendent home phone numbers. Since the police are going to be involved, the superintendent or an assistant would surely be contacted. They can get people out there to fix it. There may be some legal issues, (which the contractors are not aware of) justifying the inclusion of the watchman in some cases. But, with the current policy of *required when traffic lanes are restricted* phraseology, contractors don't know whether to include the cost of a watchman or not.

Exceptions: None

Benefits: The cost of a night watchman 12 hours a day for 6 days and 24 hours on Sunday for 2 years is about a $100,000 item. Alternatives include a security service checking the job on a regular basis at a cost of @$10,000 or sensing devices, or arrangements with the police. If the design engineer is unsure of the need at the time of the bid, it should be listed as a bid item, then if it is found unnecessary, it won't be paid.

Reasons: In the proposal book, it normally states that a night watchman will be required when traffic lanes are restricted. What constitutes a restriction, however, is often open for negotiation, and the interpretation and enforcement of this provision varies widely from district to district. This provision must be rendered more specific so that contractors are on equal terms and don't have to guess what to do, or what to bid.

Examples: When there is an existing 2 lane roadway, and all that is required is to put in some temporary widening and move the two lanes over, is that restricted? There is still a full two-lane-of-travel thoroughfare for example. See 'Restriction' Graphic

Measurement and Payment

Scope Reinforced Earth Pay Items

Guideline: Define the scope of work to be included in each Reinforced Earth pay item. Also, care should be taken to match the top of the reinforced earth walls with the adjacent roadway elevation.

Qualifiers: None

Exceptions: None

Benefits: More accurate bidding and payment for contractors, resulting in less confusion when scope of work changes during the coarse of a project. Also better historical unit costs will be available for value engineering analysis if it is known what work is included in each pay item.

Reasons: " For reinforced earth structures, the scope of work associated with standard pay items is not well defined. For example, in what pay item should a reinforced-earth-foundation excavation be included; common excavation, or one of the reinforced earth pay items?" (Walsh Construction)

Examples: View INDOT specification section on method and basis of payment.

Graphics: Picture of reinforced earth retaining wall system

Picture of reinforced earth bridge end bent

Perspective of reinforced earth system

Reinforced Earth Erection Procedures

Make Shear Studs a Pay Item

Guideline: Make shear studs a separate pay item.

Qualifiers: None

Exceptions: None

Benefits: To clear up the quantity required at the time of the bid.

Reasons: Required spacing is often not clear and a unit price at the time of the bid would clear up required costs. (Contractors United)

Examples: None

Graphics: Shear stud spacing detail

See picture of shear studs in field

Pay Item for Top Soil Dressing

Guideline: Create a separate pay item for dressing slopes and ditches with top soil.

Qualifiers: 1. This work item cannot be quantified from the contract documents. It is typically defined by the project engineer or inspector leaving the contractor to guess.

Exceptions: None

Benefits: Increases contract specificity with an associated increase in fairness to both contractors and the state.

Reasons: "If this is not done, it becomes an absorb item which the contractor has to guess about, and include somewhere. If a separate bid item, when it is needed, the state will pay for it." (Reith Riley)

One issue if this approach is taken is what units will be used to reimburse the contractor. If volume, then cross-sections would be required. If area, then field measurements made. This would be needed in order to have a seperate pay item.

Examples: .None

Graphics: None

Effect of Pay Item Errors

Guideline: Understanding how contractors prepare a bid for a pay item and can profit from either over or understated quantities on pay items, should motivate designers to be more accurate and provide better detail in an attempt to eliminate errors before the bid.

Qualifiers: None

Exceptions: None

Benefits: More accurate bid documents allow the competitive system to select the low bidder based on the contractor with the highest productivity, rather then the ones most willing to unbalance their bids and/or perform legal maneuvering after the bid. Eventually, this encourages innovation and contractors to spend their time and overhead to increase their productivity rather than on how to beat the system.

Reasons: Contractors feel forced to unbalance a bid to be low when INDOT makes errors on the bid documents. For example, '*if we do the cut and fill calculations on a project and find that the bid item for 7,500 CY of cut and waste will not be required, we will bid that $5/CY item at 50 cents, or a penny.*' They feel this makes their total bid lower, while not hurting the state because the item will not be billed anyway.

If the quantity listed is too small, i.e. there will be more actually done then the bid quantity shown, '*then I would double my unit price for that bid item, and take the dollar amount out of something else, so the total bid is the same. But when the quantity goes over the bid quantity, I get the profit.*' Contractors commonly reason further that if some contractors don't analyze the documents as well, or want to be a '*nice guy*', then their bid will be higher by that amount.

While on the surface, this reasoning appears valid, a deeper probe reveals that a lower bid, unbalanced in this manner, is just that, a lower bid. Regardless of what other competitive or non competitive pricing exists in the bid, it is lower by the amount of the unbalance. If INDOT creates this situation (with the error), and allows it to be successful; to the extent of the unbalance thus created, the state is selecting the contractor, not based on productivity or competition for lower profit, but on a contractors willingness to play the unbalancing game. Further, higher profit and lower productivity can be embedded in such a successful bid to the extent that one contractor is willing to gamble on unbalancing relative to another. While difficult to quantify, the state does indeed pay for this relative differential, as well as perpetrate its continuance through opportunistic errors and their unwillingness or inability to enforce laws against unbalanced bids.

Providing calculations on how the engineers come up with their units may help reduce this costly problem. It would be very helpful to have all the engineers calculations on volumes for both the yardage calculations with factors for loose, or compacted as well as factors for tons per yard. '*We check all quantities before the letting. What is included and how much is very important to know. It is a real issue where we don't agree. We need those calculations to sort it out. Did they make an error, or did we? Or is it a difference in our understanding of intent? Information is going to yield the best price. Ohio does that, for information only, a page or two entitled asphalt calculations etc. and they will run through how they came up with the various types of mixed quantities, and dirt calculations. Sometimes the INDOT field office has a copy of the calculations, but they are unavailable to contractors at the time of the bid.*'

Contractors are willing to pay for the calculations. And, it may be something that can put on existing prints, but when an error exists, providing the engineers calculations will have a variety of impacts. These impacts will depend on the nature of the error and to a large extent on the engineer's relationship with a contractor, as well as that contractor's time and willingness to share with the engineer errors and omissions discovered during their review. What a contractor will do when they discover an error, depends on how they view the tradeoff between these often competing ideals, as well as how they think their competition will deal with discovery of the same error.

This is a not so rare situation in the industry, and one to be carefully cultivated by design engineers. It should be observed that this type of relationship is most likely between companies operating in the private sector as well as

for INDOT. Further, it is operative whether the engineer provides the breakdown of his bid item quantities or not. Finally, it should be clear that the only way to clearly eliminate this type of game, is to eliminate the error. So, the hope is that through understanding of how the game is played, engineers will realize they must not over or under estimate bid item quantities, and will more carefully and accurately prepare the bid documents.

Examples:

" All calculations may not be necessary. Areas and yields are the problem. For example type O stone may have 100,000 tons required on the job from 50 different line items. We will break it down, into stone under drives, stone under bridge approach slab, mainline stone, etc. because the cost of the line items is radically different. If our quantity sum is radically different from the engineers' we need to know why. The average price we bid is a conglomerate of the cost of the line items. If we don't know why his item is different from ours, we can get into some major problems." (Contractors United)

"Other states have more pay items, and less absorb items. Mass diagrams would be useful." (Reith Riley)

"On Ohio and Michigan plans, for each page the quantities are listed. As we go through the plans, we check our take off against that listed quantity, and then we know if there is an error. This is a very good way of the state telling us what they want. They indicate what sheet and station is indicated and the summaries. If there is a substantial error we are going to play all kinds of games. We would like to be able to confirm the error so we can call the state. " (Reith Riley)

Graphics: None

Barrier Wall Pay Units

Guideline: Specify pay item for barrier walls by the foot.

Qualifiers: None

Exceptions: None

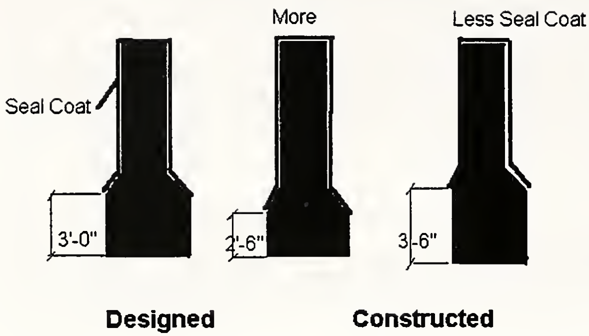
Benefits: So that masonry coat and surface seal will be appropriately adjusted if depth of wall is changed in the field.

Reasons: If walls are bid by the cubic yard, a wall height adjustment below grade which is not sealed, will result in a deletion of some pay for surface seal which still must be performed. (Contractors United)
See Barrier Wall Graphic.

Examples: Example of cost impact of using Cubic Yard method.

Graphics: See picture of barrier wall

See Below



Utilities

Utility Planning

Guideline: Design Engineer should plan for site surveys, subsurface engineering, right-of- way staking, and scheduling and management of utility relocation on all INDOT projects.

1. Review and alter design drawings (including their location on cut sections through phased temporary trafficking systems), and specifications to accurately reflect subsurface engineering for the respective utility. Provide both mobilization time and performance time requirements in the special provisions.
2. Special provision commitments detailing utility plans for prerequisites, mobilization and performance, including liquidated damages for time delays between the utility and the contractor. Line items in the bid for

per-working-day delays due to utility caused hold ups as required for specific job tasks or required phases of construction.

3. Right-of-way staking for all INDOT projects before bid letting, and if needed, early enough to enable all economically feasible utility relocation prior to bidding.

Qualifiers: None

Exceptions: None

Benefits: This process would save 30-45 days on nearly every project bid by INDOT, which involve the need to move utilities to accomplish the construction. This time savings reduces contractor overhead by its cost of from $10,000 to $20,000 per month, increases equipment utilization by 10% per month saved, and enhances competitive bidding as well as labor wage negotiations. Requiring the designer to manage utility relocation is much more economical than with the contractor involved. Multiply the $10,000 to $20,000 per month savings per project to all applicable projects is an expense into the millions of dollars that can be recovered partially annually.

Reasons: Utility interference and relocation can be time consuming and costly on projects, especially when the contractor's activities are impacted. A more efficient process is to require the designer to work with the involved utilities and schedule the location surveys and relocation efforts. A checklist of utility coordination activities should be developed by INDOT design division and included as contractual requirements for consultants. The design reviewer will verify that these requirements have been performed. Contract letting will inform the designer when the project will be let. Enough time should be provided to allow coordination for utility location surveys and utility relocation. This coordination will become the responsibility of the project designer.

Examples: "The power company on a recent INDOT project had been given verbal permission before the bid to relocate their lines. But, the approved location did not appear on the bid documents. And when discovered by the contractor, it conflicted with the required temporary traffic facilities, effectively closing off dozer and crane access to the project, as well as seriously confining the remaining working envelope due to the need to avoid the crane boom coming closer than 10-15 ft from high voltage wires." (Sweet 1993)

"Often, the centerline of the temporary road is given, but not the outside limits. It is essential to draw the whole temporary road where it is going to be; the shoulders, toe, etc., to see how it infringes on other temporary structures and permanent construction processes. The locations of these 3 utility poles were not shown on the plans. It wasn't until the utility company was out on the job setting the poles, that the contractor discovered the problem." (Sweet 1993)

"This happens frequently with utilities. Poles are not where shown. Cranes with crawlers are typically 12.5 ft wide. The 'approved' location allowed only 10 ft for temporary passage. Further, they didn't leave enough room to get under the power lines with the crane. The result of these extraneous utility plans changed the whole modus operandi of the job. The design for temporary access must consider not just the location of the poles, but also a 4-8 ft cross arm and wires on the poles which may be only 20' high when 80 ft of clearance may be required for the crane boom." (Sweet 1993)

Due to utility design and environmental restrictions, heavy construction equipment owned by contractors and rental companies are currently utilized an average of 6 out of an 8 to 9 month season. Amortization costs must be reflected for this potential utilization in the establishment of unit prices to bid. Union labor rates are also negotiated based on 6 month utilization period as a result of these restrictive provisions. This and indiscriminately applied environmental contract provision effectively cost the state 20 to 30% more in labor and equipment. Finally, the lack of attention to utility design does result in contract cost increases. The state tax payer, contractor or utility user is going to pay more, for a lack of attention during design, to the impact of utilities; costs which can and should be avoided. (Sweet 1993)

"We were told verbally and in writing that there was a gas line on a job, but that it was completely out of the way and would not cause any conflict. The first hour on the job, our cat operator fell into a hole and ruptured an 8-inch gas line. A man could have been killed and it cost our insurance company $10,000 to avoid a court battle. So, we now take the attitude that we want the utilities moved completely out of our road." (Sweet 1993)

"Utilities are one of the biggest holdups to getting into production. Need more time spent locating underground utilities and making sure they are located on the plans? We have hit 12 inch water lines and on other jobs had to redesign drainage systems on a day to day basis due to things not being as designed. Overhead utilities should be removed before the bid. And if not, then clearly state that they will not be moved. Time frames are given in the bid documents, but no start or ending dates are given." (Beaty)

"Drainage pipe elevations should be checked for interference with roadway subgrade elevations. A six week

delay in a project occurred because a pipe was hit while grading the subgrade. This caused a redesign to be made." (Walsh Construction)

Special provision requirement of clearing before utility work is causing double mobilization for contractor and costing the state a lot of money. State is requiring the following:

Mobilize
Clear site
Utility work
Re-mobilize
Start work

This doubles and triples the cost for this part of the project. A least cost solution is to require the utility to clear and do its own traffic control. (Primco Construction)

"During the design stage, the designer should contact the power company and study the impact on construction operations. Overhead power lines affect the feasibility and productivity of crane operations. For example, when setting a temporary wall, demolition, or driving piling. The power company had to ground the lines and shut some down." (Weddle Bros. Construction)

See video of overhead power lines and construction equipment operation.

Graphics: None

Notes: EXISTING UTILITIES

The most common utilities are electric, gas, telephone, cable television, sanitary sewer, storm sewer, and water. Most utilities have a permit from a governmental agency for construction and maintenance of their system within the public right-of-way. For this reason, it has become the practice for many designers to assume potential conflicts will be eliminated by having the utility agency relocate their structures. In many cases, this assumption is made with little or no assurance of compliance by the utility owner.

If the design assumes relocation, and if this is not accomplished prior to construction, the complexity of construction increases. It is also more likely that the time for construction increases or that it will be delayed while the conflicting utility is relocated. No matter how much time is given to the utility agency, typically relocation will not begin until construction of the project has begun. Therefore, construction costs will increase because the utility contractor and the project contractor will be working in the same vicinity at the same time period, necessitating more coordination by the project contractor. The cost of providing the coordination is going to be passed to the contract, either as part of the bidding process or through extra cost items.

In many situations, there are solutions to potential utility conflicts other than relocation. As an example, the following field modification was made on two different roadway rehabilitation and widening projects to solve a conflict with an existing telephone duct:

From approximately 3.5 feet to 4.8 feet from the project limits, a 12-duct telephone conduit was shown on the plans to be in conflict with proposed catch basins, (in this application, the catch basin has a 33 inch sump). As designed, several thousand feet of telephone duct had to be relocated to install the catch basins every 150 to 200 feet.

In order to eliminate the conflict without relocating the conduit, a field change was made to install inlets, with no sumps, and connect them to the repositioned catch basins.

The additional cost of the inlets was borne by the telephone company. It was estimated that relocating the line would have cost in excess of $75,000 while the inlets, for the same section, cost approximately $10,000.

In order to eliminate conflicts with existing utilities, the location, both horizontal and vertical, must be known. Utility atlases are not accurate in most cases. Exploratory surveys should be performed to accurately determine location. Additional cost to the design of the project may be incurred, but this cost will be significantly less than additional construction costs which may be necessary to construct the improvement as designed without this information. Cost savings to the utility agency are also important, and may be realized if it is not assumed that the utility will be relocated to alleviate the conflict.

It is important to remember the following when designing a roadway rehabilitation if potential conflicts exist between the proposed improvement and existing utilities:

1) All utility structures, both existing and proposed, have a size and shape. They are not just a line on the plans or symbols used to represent the structure. Obtain the size, shape, and location of existing structures, either through as-built plans or test holes.

2) If a proposed system is to be placed parallel with and deeper than an existing system, leave enough distance between them so an undisturbed bank of earth remains. If the existing system has to be supported, special construction practices must be followed, which always cost more than standard construction practices.

3) Think about and identify what to do with all existing utility structures if they are in conflict. It is easier to make these decisions during design, with all supporting information nearby, than it is in the field with little or no information and a client and contractor concerned about delays and additional costs. In addition, the cost probably will be less and the constructed product may meet the project requirements better.

4) Work with the utility company. If money saving options are offered to them, they will be more receptive to helping alleviate potential conflicts. Simply expecting them to relocate will close avenues of communication and may force field personnel to reach undesirable conclusions about what alternatives are available when under the pressures of construction.

Environmental

Site Clearing for Indiana Bat

Guideline: Investigate the applicability of DNR time restrictions on Site Clearing for each project and apply for permits prior to the bid.

Qualifiers:

1. Is the project simply a realignment, with all ground clearing within 100 feet of an existing road? If so, the provision doesn't apply.
2. Lack of planning and coordination with utilities prior to the bid, may also limit contractor use of this prime construction period.
3. Lack of detailed investigation by DNR for protection of fish habitat may also limit use of a portion of this period.

Exceptions:

1. Does a special provision exist from DNR restricting all clearing between May 1 and September 1?
2. Do these dates conflict with the projected start up of the contract?
3. Is this a relocation with all ground clearing within 100 feet of an existing road? If so, the provision doesn't apply.

Benefits: Lifting the restriction or narrowing it in time and scope to what is actually needed to protect the Indiana Bat; reduces contractor overhead by its cost of from $10,000 to $20,000 per month, reduces INDOT project management overhead and traveling public cost by the project time reduction of at least 1-2 months per job, increases equipment utilization by 10% per month saved, and enhances competitive bidding as well as labor wage negotiations.

Reasons: Many state contracts include the following special provision: "To minimize project-related impacts on the Indiana bat, *Myotis Sodalis*, all clearing shall be performed between September 1 and May 1, when the bat is not expected to be in the project area." The provision was instigated to protect the endangered bat habitat throughout the state during these periods from destruction due to construction clearing. Site clearing is usually the first required activity on the project, is on the critical path and until it can be performed precludes the start up of all other site activities. Bats will not usually come within 100 feet of an existing road. Therefor, after the bid, and at the request of the contractor, this blanket provision is often limited to clearing restrictions beyond this 100-foot zone by DNR. If the provision as written is in force during the bid, however, the contractor is led to believe that a contract bid in May could not begin until September. So, some contractors may decline to bid if they are led to believe that they will not be able to begin construction until after the prime construction season. This reduces contractor interest and thus the competitive performance of the bidding process. The provision's cost impacts may be included and eventually paid by the state even if eventually lifted.

Examples: An 8 to 9 month construction season exists in the state of Indiana. The season begins in March or April and ends in October or November. While causing no impact on the bat's habitat, if this and proper planning for utilities were accomplished prior to bidding, it would provide for maximum utilization of available labor and equipment resources during the full 9 months. The construction of both new bridges, temporary bypass structures and roads usually require some clearing. The logic and inconsistency of the application of this provision seems to baffle contractors. Uncertainty increases contract cost at the time of the bid. After bidding, cost and time savings, if achieved, stay with the contractor. If the state would do the detailed investigation initially, and include only those provisions which specifically apply, the savings would be theirs. As a result of this provision, in channel excavation restrictions, and utility coordination problems, heavy construction equipment, owned by contractors and rental companies in the state of Indiana, are currently utilized an average of 6 out of an 8 to 9 month season. Amortization costs must be reflected for this potential utilization in the establishment of unit prices to bid. Union

labor rates are also negotiated based on 6 month utilization period as a result of these restrictive provisions. This and similar indiscriminately applied blanket contract provision effectively cost the state 20 to 30% more in labor and equipment.
Graphics: None

Rule 5 Interpretation and Enforcement

Guideline: Have erosion control plans designed as part of the bid documents and paid for as a bid item, applied for by the state prior to the letting. If over 5 acres and the permit is required, then have the state apply for the permit and make it transferable to the contractor. (Reith Riley, Beaty, Switzer & Huckleberry)

Qualifiers: None

Exceptions: None

Benefits: Reduced construction time and uncertainty at the time of the bid.

Reasons: " Erosion control/Rule 5 permit requires a considerable amount of time in the application process. The federal guidelines are not specific to a contractor. Some options exist, but basically the requirements are specified for the type of operation to require type 'A' or type 'B' erosion control. It could be done prior to the letting. Further, it could be a difficult problem to really enforce keeping all the sediment from a bridge construction project on site, not letting it get into the stream. Just what is to be done and how, is a design function." (Switzer & Huckleberry 1993)

Examples: None

Graphics: See Graphics for examples of Type 'A' and Type 'B' Erosion control.

Type 'A' Detail - RipRap Ditch Check
Type 'A' Detail - Straw Bale Ditch Check
See Picture of Straw Bale Ditch Check
Type 'B' Detail

Environmental Permits Before Bid

Guideline: IDEM permits -- The Indiana Dept. of Environmental management requires a permit for any demolition, technically. We would like them to handle that prior to the letting. (Switzer & Huckleberry 1993)

Qualifiers: 1. The designer needs to make an assessment of what permits need to be applied for before bid date and after by the construction contractor.

Exceptions: None

Benefits: Analyzing permit needs and starting or performing the process before construction can eliminate troublesome and costly delays caused from waiting on permits.

Reasons: When a contractor is prevented from working because permits have not been approved; this creates a costly wait because the contractor may be able to justify a request for extra. The contractor can charge for overhead expenses and equipment costs incurred by the delay. Also, a delay typically causes changes in the construction schedule which sometimes creates cost increases in latter activities.

Examples: Linked to this lesson is Design Memorandum #24 dated June 13, 1994(1).(Scroll the memorandum by using the arrow keys) This memorandum contains information regarding environmental permits and requirements, Indiana Navigable waterways, U.S. Army Corps of Engineers Section 404 permit(2) activities, and definitions used in Section 404 permit application process. This information is intended to help the designer determine environmental permit requirements or project justifications. This memorandum does not cover the designer's responsibilities for permit application forms or the permit application procedure. See pop-up for definitions used in Section 404 permit(3).

Graphics: None

Underground Storage Tank Removal

Guideline: Provide Contractors and the district project engineers with an itemized, step by step procedure of what they are to do when they run into gas tanks and/or contaminated soil. It should identify who is involved, and who to contact if they hit one of these things when it is not shown on the plans.

Qualifiers: None

Exceptions: None

Reasons: This is becoming a more frequent and unexpected event. This is all in-house, but it still has a lot of conflict between departments. (Switzer & Huckleberry 1983) What to do has been investigated and outlined by many sources. Reduction of contractor and INDOT uncertainty with a clearly defined if-then rule base with examples and phone numbers is clearly achievable.

Examples: None

Graphics: The five picture listed below is the typical sequence of how an environmental consulting firm removes underground storage tanks under the appropriate compliance.

Picture 1: Clearing the concrete for excavation of UST's
Picture 2: Pulling the tanks out of the ground.
Picture 3: Location of USTs. Notice groundwater and soil contaminants
Picture 4: Getting tanks ready for shipping
Picture 5: Job complete. Tanks on their way to recycle plant.

View a Video on the use of Bioremediation to cleanup a UST site contaminated by petroleum byproducts.

State Specific In-Channel Restrictions

Guideline: Investigate the applicability of Department of Natural Resource (DNR) time restrictions for In-Channel excavation on each project prior to the bid.

Qualifiers:

1. Does a special provision exist from DNR restricting in channel excavation between April 1 and July 1st on the project?
2. Do these dates conflict with any of the projected time of the contract?

Exceptions:

1. Are fish actually spawning in the contract area during the restricted times?
2. Lack of planning and coordination with utilities prior to the bid, may also limit contractor use of this prime construction period.
3. Lack of detailed investigation by DNR for protection of Brown Bat habitat may also limit use of this period.

Benefits: Lifting the restriction or narrowing it to what is actually needed to protect the state fish; reduces contractor overhead by its cost of from $10,000 to $20,000 per month, reduces INDOT project management overhead and traveling public cost by the project time reduction of at least 1-2 months per job, increases equipment utilization by 10% per month saved, and enhances competitive bidding as well as labor wage negotiations.

Reasons: Many state contracts include the following special provision: "To minimize project-related impacts upon fish spawning, no in channel excavation shall take place between April 1 and June 30." The provision was instigated to protect fish migrating or spawning throughout the state during these periods from construction induced silting. At the request of the contractor, this blanket provision is often reduced or eliminated after the bid (pending a detailed site investigation of temperature, species, and other factors by DNR). If in force during the bid, the provision's cost impacts are included and eventually paid by the state even if eventually lifted.

Examples: An 8 to 9 month construction season exists in the state of Indiana. The season begins in March or April and could proceed, making use of available labor and equipment resources during the full 9 months, if this and proper planning for utilities were accomplished prior to bidding. The construction of both new bridges and temporary bypass structures require in channel construction. DNR's broad generalization has been applied during bidding to dry stream beds and small ditches carrying apparently uninhabitable runoff, regardless of size. A wavier, if applied for after the bid, results in a site visit by DNR, and frequently an allowance for certain types of in-channel work to be done for specific time frames and activities. Cost and time savings, if achieved, stay with the contractor. If the state would do the detailed investigation initially, and include only those provisions which specifically apply,

the savings would be theirs.

Note: "A small project reserved for minority owned businesses was bid in November. Because of environmental restrictions work could not start until June. This would require the low bidder, in this case a small contractor, to tie up the bid amount as bonding capacity. This may prevent the contractor from bidding if it consumed the bonding capacity. If this happens then the contractor would increase the bid to pay for this waiting period." (Shutt 1993)

Note: There needs to be some actual determination of whether they are going to waive it or not. A typical example would be Highway 26 west of Lafayette. The contract stated both restrictions, eliminating clearing from May 1 to Oct. 1st and all in channel excavation from April 1 to June 30th. The project was let in March, with a notice to proceed in April. These restrictions basically eliminated this year's work. Both were pulled after the bid. The designer needs to make this determination before bidding.

Graphic: See picture of in-channel work.

Structures

Foundations

Use Cofferdam Bottom Seal

Guideline: If extending an existing bridge, the designer should check existing bridge foundations to determine if seals were used. If seals were used, then they should be specified again.

Qualifiers: 1. Check soils report information and recommendations.
Benefits: This is a safety issue at the job site.
Reasons: The use of a concrete seal at the bottom of a coffer dam avoids bottom blowout. The workman's lives can be lost if this rather sudden quick-condition occurs when they are in the hole. It is caused by a combination of high hydraulic head and susceptible soils. A seal is costly, and the engineer should consult old field records to see if the existing bridge foundations required them during construction.

Source: Weddle Bros. Construction

Procedures for installing a seal

1. Remove the soil inside the cofferdam (through clamming or some other technique) to the elevation of the seal bottom. (Cofferdam is not dewatered)
2. Install the foundation piles to desired tip elevations or bearing capacities. When driving piles a "crib" should be used to properly position and space the piles. Caution should be used when battered pile are used with a foundation seal. Cofferdam sheeting may interfere with their driving. Also, the tops of other piling may be in the way since they cannot be cut off until the seal is poured and the water removed.
3. Place seal concrete using the tremie method. (See Detail of Tremie method) For the concrete pump option, the discharge hose is submerged in the water as far as possible but does not come in contact with the bottom. This procedure helps eliminate any separation of the mix. (See Picture)
4. A vibrator is used frequently during the placement to help limit the amount of voids in the cofferdam bottom seal.
5. The elevation of the seal is predetermined by several variables. One being the required depth of the pier and another is the amount of predicted piping that might occur due to the water head.
6. Random measurement of the seal elevation during the pour is accomplished by submerging a measuring tape in the water until it rest on the top of the poured concrete and measure to the top of a cofferdam frame. (See Picture)
7. Once the seal has been placed and cured, dewater the cofferdam and cut the pipe piles off at grade. (See Picture of dewatering pumps).

See picture inside the cofferdam cell at this stage.

Graphics: See Video for construction process to install seal.

Deep Foundations Alternatives

Guideline: Alternatives to conventionally formed deep foundations should be considered.

Qualifiers:
1. Consider using alternatives when footings are very deep;
2. When excavations to form the foundations require adjacent streets and roads to be protected and braced, or;
3. Under poor soil conditions and high water table, such that a quick condition may develop, and bottom seals will be necessary.

Exception: 1. The use of other deep foundation alternatives.

Benefits: Substantial cost reduction and time saving.

Reasons: Formed deep foundations require sheet pile cofferdams to access the form. The cofferdam is at least a $50,000. item and may run $70-$100,000 depending on the size, required depth and/or bottom seal. Consider alternatives of driven precast piles or drilled (temporarily cased) and cast in place piers.

Example 1: A pier is simply a column, usually of reinforced concrete, constructed below the ground surface. It performs much the same function as a pile. That is, it transfers the load of a structure down to a stronger rock or soil layer. Piers may be constructed in an open excavation. Since piers are often constructed by filling a caisson with concrete, the terms pier foundation, caisson foundation, and drilled pier foundation are often used interchangeably.

A caisson is a structure used to provide all-around lateral support to an excavation. Caissons may be either open or pneumatic. Pneumatic caissons are air- and watertight structures open on the bottom to permit the excavation of soul beneath the caisson. The caisson is filled with air under pressure to prevent water and soil from flowing in as excavation proceeds. To prevent workers from suffering from the bends upon leaving pneumatic caissons, they must go through a decompression procedure like that employed for divers. Because of the health hazards and expense of this procedure, pneumatic caissons are rarely used today.

Drilled piers are piers placed in holes drilled into the soil. Holes drilled into cohesive soils are not usually lined. If necessary, the holes may be filled with a slurry of clay and water (such as bentonite slurry) during drilling to prevent caving of the sides. Concrete is then placed in the hole through a tremie, displacing the slurry. This procedure is similar to the slurry trench excavation method.

Holes drilled in cohesionless soils must be lined to prevent caving. Metal or fiber tubes are commonly used as liners. Linings may be left in place or they may be pulled as the concrete is placed. Holes for drilled piers placed in cohesive soil are often widened (or belled) at the bottom, as shown in below figure, to increase the bearing area of the pier on the supporting soil. Although this increases allowable pier load, such holes are more difficult to drill, inspect, and properly fill with concrete than are straight pier holes. (Nunnally, S.W., Construction Methods and Management)

Example 2: " On a project, the subsurface investigation showed blow counts of 3-4, a very unstable material for 10 to 12 feet below the bottom of some footings. The only way to excavate that material and replace it with engineered fill was to put in cofferdams at about $40,000 to $50,000. each. Rather than requiring the contractor to build sheet pile earth retaining cofferdams, the designer should have considered precast piles, or another type of foundation." (Leon Beaty)

"We had 35 ft piling set up on a project and could drive them only 15 feet. On another project, we had 15 ft piling set up and drove them 50 feet. Tiebacks -- drilled & pressure grouted earth anchor systems require borings in the area of the anchor to enable the establishment of holdback capabilities, per AASHTO and others. Soil investigation information is crucial in making these design decisions." (Leon Beaty)

See Figure for Drilled Pier

Figure for Drilled Pier Construction Procedure

Graphics: Video of removing sheet piling to construct deep foundation

Accurate Pile Lengths

Guideline: Specify pile lengths based on blow counts, old pile driving logs and informal discussions with area

engineers and local knowledgeable residents, in addition to the wave equation.

Qualifiers: 1. Apply this concept when using H-Piles or Shell piles.

Exceptions: 1. Note: more research is required to establish the utility of and quantify this rule of thumb.

Benefits: Lowers total cost for piling due to reduced over and under estimates for the required length of driven poles, and improves competitive bidding.

Reasons: Inaccurate pile length estimates are very costly because the contractor can only order the estimated lengths prior to driving the piles. Current practice provides an estimated minimum tip elevation, but they should be designing on an estimated pile length. We seem to always overrun the pile length by 10-12 ft. (Switzer & Huckleberry 1993)

If the estimated length is too short, the equipment must wait, @$80-$160 / hr or remobilize @$1500-$3000. to allow additional material to be procured.

If the piles are estimated too long, more material will be procured than required, with reshipping and restocking charges deducted from any balance. The epoxy coated top section may not be welded to the top of the pile and hence its protection would not be afforded that pile in the corrosion zone. Also, a wise contractor that can accurately estimate a significantly shorter length than the units in the line item estimates, can and routinely do (illegally, but successfully) unbalance the bid in their benefit to get the job by listing very low values for items they believe will not be supplied, which lowers their net bid. Removing the potential for windfalls like this reduces uncertainty and promotes better overall competitive bidding.

Examples:

INDOT has replaced the ENR pile driving formula with the Gates Formula to monitor pile driving operations. The **Gates Formula** is shown below.

$$Ru = 0.5[1.75\sqrt{E}\ \log(10N) - 100]$$

Where: R_u = The ultimate pile capacity(Tons).

E = The manufacturer's rated hammer energy(Foot Pounds) at the field observed ram strokes.

log(10N) = Logarithm to the base 10 of the quantity 10 multiplied by N the number of hammer blows per 1 inch at final penetration.

<u>Rule of Thumb:</u> Jim Sweet of J.S Sweet Co. Inc., Contractors has found that a blow count of 50 will produce a 40-ton bearing end condition for H-piles commonly used for INDOT bridges. For shell piles, the 40-ton requirement is typically achieved at a location in the soil profile with a standard blow count of 40.

Graphics:

Picture of a pile driving rig.
Pile splice and corresponding engineering design drawing.
Audio clip describing pile driving operation.
Video of pile driving rig setup.
Video and Sound Clip of Pile Driver Analyzer Operation.

Bridge Abutment Forming

Guideline: Design bridge abutments to be poured before the deck is placed, and use straight as opposed to sloped faces.

Qualifications: None
Exceptions: None

Benefits: Reduced time and cost for construction.

Reasons: Pouring the back wall of a bridge abutment is very difficult because of the requirement to construct it after the deck is in place. This creates a restricted work area at the bridge end and makes it difficult to build the forms and make the pour. It would be much easier to pour the abutments before the deck is placed. Also abutment

and pier details that have sloping faces to save concrete takes longer to form and are in most cases more expensive. (Walsh Construction)

Examples: None

Graphics: See graphic of back wall bridge abutment.

See video of restricted work area at bridge end.

Avoid Camber Ponds

Guideline: Move vertical curve PI's to one end or another of a bridge to avoid the ponding effect of multiple span cambered beams. (Primco Construction)

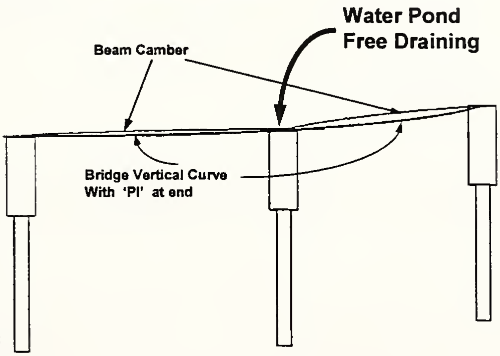
Qualifiers: 1. If the bridge is in a vertical curve and cambers are required, then one camber diagram cannot be used for all beam spans. Check each span condition for camber requirements.

Exceptions: None

Benefits: Higher quality, longer lasting finished bridges due to decreased water ponding.

Reason: When bridge is located in vertical curve and the beams cambered, a ponding effect is created over the center pier.

See Ponded water Graphic
The solution is to move the PI to one end of the bridge.



See Solution Graphic

Examples: None

Graphics: None

Pier Cap Extensions

Guideline: Design pier cap extensions to enable the contractor to simply, drill, dowel, and epoxy into existing cap to tie on the extension.

Qualifiers: 1. The designer should determine if there is any reduction in the pier capacity with this option

Exceptions: 1. Another option is to extend the existing foundation and construct a new column line to support an additional beam line.

Benefits: This option is quicker, easier, and cheaper for the contractor. (Weddle Bros. Construction/ Primco)

Reasons: Two common methods exist:

1. Remove concrete back to existing column reinforcement, by Jack hammering. (See video clip - Jack hammering of cap.)

2. Drill, Dowel, and Epoxy into existing cap after simply cleaning it to obtain good bond.

Examples: None
Graphics: Video of Pier Cap Extension Process.

See **video** that shows the option of extending a pier cap by extending the foundation and constructing a new column line.

Forms

Stay-in-Place Deck Forms

Guideline: Stay-in-place forms should be redesigned to allow water which penetrates the slab to evaporate from the bottom of the form. A long term solution is needed which will take advantage of the labor savings associated with stay-in-place forms, provide an acceptable under finish and yet will not trap water which penetrates the slab.

Qualifiers: None

Exceptions: None

Benefits: At least 10% savings exist for use of the stay in place forms at the time of construction. Over heavy traffic areas the savings is about 25 to 40% over standard forming systems.

Reasons: But the current type of form seals up the flow of water through the slab and can result in a reduction of the structure's life. (Beaty Construction Company)

Examples: Stay in place forms should at least be very heavily galvanized to avoid long term maintenance. But galvanizing will still only provide about a 20 to 25 year life.
Consider perforating the stay in place forms to allow water penetrating the slab to evaporate from the bottom.
Expanded metal type stay-in-place bulkheads have been used for several years. If used under a bridge, however, this may provide an unacceptably rough finish.

Graphics:
Picture of stay-in-place forms installed.

Picture of stay-in-place forms and span information.

Deck form details - Page 1

Deck form details - Page 2

See video of deck form installation.

Standardize Round Column Diameters

Guideline: Standardize round column diameters at 24 inch +6 inch increments. See form supplier brochures for sizes smaller than 24 inches.

Qualifiers: 1. None

Exceptions: 1.None

Benefits: Lower total cost of column construction.

Reasons: The extra concrete is worth it to avoid special form rental, or sonotube purchasing. (Reith Riley)

Examples: See Pictures of Column Forms.

Column Picture Form 1

Column Picture Form 2

Picture of Round Bridge columns

Graphics: See Table of Standard Column Form Sizes

Architectural Bridge Pier Column

Guideline: Pier columns should generally not be tapered and should not vary in width or thickness from adjacent column piers. Sizing should allow the use of standard forms, prefabrication and setting of both forms and rebar cages.

Qualifiers: The bridge is under 1,000 feet. The concrete and steel requirements for the worst case are no more than 50% larger other column designs.

Exceptions: One or two modifications in width or thickness parameters could be economical if they result in a 20-30% reduction in material usage and each size of form can be reused on the project at least 15-20 times.

Benefits: This avoids the cost of custom forms, and reduces forming costs which generally exceed savings from material quantity reduction, except under the conditions outlined above.

Reasons: Height variations can be easily accommodated within a form which is assembled once for the tallest pier. A tapered form is about 50% more expensive than a non-tapered form. Tapering in 2 dimensions doubles or triples the forming cost. A custom form which is tapered and curvilinear in one or 2 dimensions may cost 5 times that of a standard form. Such a form cost could easily exceed the value of the cast pier. Thus architectural flairs if justifiable for esthetic reasons, should be confined to an area above a straight shaft. The straight shaft will economically accommodate height variations. Fifteen to 20 reuses of an expensive form will reasonably amortize its cost, one or 2 reuses will not. Column tie in bars should extend vertically into the pier cap and avoid hooks to allow setting of a prefabricated cap rebar cage.

Examples: Tapering a round nose creates a custom design. Varying the height, width, or thickness within the tapered area creates the need for a new custom form each time such a variation occurs. This design created this condition and a form cost which was more than the pier. Note taper, batter , and round nose combined to result in a new, very expensive custom form on each column whose height varied along the length of the bridge. A redesign of this project saved $10,000 to $15,000 per column pier.

Cross-section E-E , Pier Section and Elevation shows the redesigned pier, sized to allow the use of standard 6 foot flat and readily available 48 inch diameter column forms. The height and rebar varied, but not the column width or thickness. The rebar spacing and location was designed to allow prefabrication of the column cage and setting the prefabricated pier cap cage above it. This design easily accommodated superelevating pier caps as well. The 6' panel is a standard EFCO panel 6-8 inches thick. This means the form will require only a few snap ties after setting rather than extensive internal and external bracing that a nonstandard or custom form may require. See Figure of straight pier section comprised of straight panels and ends of column forms.

All 4 columns on this project used the same form. This is because all the dimensions remained the same except for height. A form assembled for the tallest column was used again for the other three. This design easily accommodates superelevating the pier cap as well. The contractor was able to completely prefabricate his rebar cage and forms at ground level. Brackets for screw jacks were cast in the top of the column, the form was lowered on top of the brackets and the prefabricated rebar cage set in with a crane. Because the cap was 6 inches wider than the column, the straight vertical column bars did not interfere with setting and adjusting the cap rebar cage.

Graphics: See picture of architectural pier.

Bridge Pier Cap

Guideline: Design pier caps 6 inches wider on each side than the width of the supporting columns. The pier cap reinforcing cage should then be designed so that it can be prefabricated on the ground and dropped down over the vertical column tie-in bars. (Avoid hooks on the column tie in bars.)

Qualifiers: None

Exceptions: None

Benefits: Avoids the expense of building a custom form and elevated piecemeal assembly of rebar systems.

Reasons: The 6 inch width provides for brackets and screw jacks on the columns. This allows a prefabricated pier cap form to be placed, adjusted, and anchored on the cast column stem.

Examples: This design allows the contractor to use 2 vertical EFCO panels with a soffit in between.

Graphics: See Picture bridge pier cap forms

Standardize Forming Sizes Etc.

Guideline: Provide designers with standards for design of beam length, widths between beams, reinforcement, etc. together with variance costs.

Qualifiers: 1. None

Exceptions: 1. None

Benefits: Reduced cost for design, detailing, and construction.

Reasons: Lengths of beams, widths between beams, rebar reinforcing, negative steel over the piers, seem to change on every bridge structure. Standardization is not a criteria for design, and it should be. One of the largest costs for a contractor is building and setting the form, if that could be standardized, money could be saved. This enables a contractor to standardize materials and procedures. For example box culverts. If the spans are the same, after you get up out of the ground, there is very little reason for not standardizing nearly everything. (Beaty Construction Company)

Examples: None

Graphics: Show required form changes to accommodate variations typically used.
Provide charts for the costs of alternatives.

Concept 1
Consider wider and deeper steel girder spacing
Typical Bridge Cross-section
Typical Bridge Section
Typical Girder Elevation
Concept 2 -Web to tension flange stiffener
Typical connection Plate
Typical Connection Location

Concept 3 - Use of seismic isolation bearings
Typical seismic isolation bearing

Concept 4 & 5 - Pier stems and Capitols
Typical Elevation
End Elevation
Pier Cap Section

Bridge Deck Overhang

Guideline: The slab overhang distance (coping line to centerline of the exterior girder) should be made as large as possible.

Qualifiers: This distance, however, shall not exceed the maximum of 0.4 x interior girder spacing or 0.85 x web depth.

Exceptions: A minimum distance of 2 ft 0 in is recommended.

Benefits: Lower material, erection, and forming costs. A savings of about 25% over using the 2 ft 6 inch standard used through 1992 can be achieved.

Reasons: The 2'6" overhang limit was imposed by a 15 year old problem of a limited number of brackets available for construction. If extended, the brackets had the tendency to rotate during pouring, which caused cracking in the slab above the outside beam. There are now brackets available and in common use which prevent such rotation. No limits are imposed by the current brackets. Thus the overhang width is not constrained by the availability of effective construction equipment and the system should be optimized on the basis of other design criteria.

Examples: See example of a recently designed bridge.

Sources: Leo Spaans, Dayton Superior, EFFCO Forming systems.

Graphics: See Picture 1 (Installation Process) and Picture 2 of Overhang Bracket

See video for the installation process.

Concrete

Concrete Strength

Guideline: In bridge structures designers should consider designing for the highest strength and most dense concrete economically available in the project location. This can generally be achieved by increasing fly ash content rather than by increasing cement, which increases shrinkage.

Qualifers: None
Exceptions: None

Benefits: Thinner, more durable concrete slabs which are denser and allow less penetration from salt chlorides and water which is the main contributing factor in freeze/thaw damage.

Reasons: The additional cost is negligible considering the long term life of the structure. Five to 6,000 psi concrete is easily achievable in Indiana using fly ash and superplasticisers to keep water cement ratios low. It is well worth the expense.

The specifications has some strict limitations for the use of fly ash. It says that only one source will be used and will be subjected to random assurance testing. Test failure will prevent the use of the material in mix design.

Examples: Standard concrete strengths in Florida DOT bridge work is 5500 psi. This is achieved by using fly ash or silica flumes. The aggregate used in Indiana is typically stronger than Florida's. So this strength is achievable. Concrete clear cover should be 2-1/2"(1-1/2" for clear cover + 1" wearing surface) for top bars in slabs.

Graphics: None

Establish a Uniform Joint Spec.

Guideline: INDOT needs a uniform joint specification. Don't use copper expansion joint water stop seal, use PVC or neoprene rubber. In any case, make it clear; if only one type is acceptable, then don't put in additional special provisions to provide some other options. (Reith Riley)

Qualifers: None

Exceptions: None

Benefits: Lower costs and higher value.

Reasons: Pier construction joints are a major source of pier cap damage because it serves as a conduit for salt and

water. The copper is very expensive to purchase and use, and results in a lower quality job. (Leon Beaty)

Examples: Some designers are still specifying antiquated copper water stops.

Graphics: See picture of bent with vertical joints.

Precast and Prestressed Concrete Members

Use of Modified Bulb-T Girders

Guideline: Consider the use of a modified Bulb-T girder on spans of 80 to 90 feet in lieu of standard AASHTO girders on 60 to 70 foot spans.

Qualifiers: 1. None
Exceptions: 1. None

Benefits: The modified T-Bulb girder provides a 30% more efficient moment of inertia as well as enhancing other section properties. This will decrease the number of girders and piers required and the square footage of forming needed for the deck. Further the beams require no strong backs for transport or lifting, and need no permanent diaphragms for stability after the deck is poured. Finally, current designs usually require no thickened webs or post tensioning.

Reasons: Due to the wide top flange, T-Bulb girders are stable during transport. The labor intensive strong backs are not needed. It cost about $16,000 to modify a standard AASHTO girder form to make this beam, and it is now available at Hydroconduit and other precasters around the state. Weight and size are a big disadvantage in transporting to the jobsite. For example two members were dropped enroute to the U.S. 231 bridge or the Wabash in Tippecanoe county.

Examples: If the job is big enough, the designer can economically modify a standard form that can then be used many times on the project. In this case the form change added about $3.00 per foot to the beam cost. At the same time it eliminated 2 rows of beams, and 3 piers. It also reduced the forming square footage by about 12,000sf @ $3.50/sf. In all $250,000 to $300,000 were saved on this 1600 linear foot $2.5M bridge.

The contractor on the project, Bridge on Shadeland Ave. over Fall Creek in Marion County, requested and was approved a redesign of the Bulb-T members. By increasing the member's depth by 6 inches a pier was eliminated saving approximately $200,000. This saving was shared with the contractor since they initiated the redesign. Had the designer used the design then INDOT would have received the complete amount.

Producing these members and delivering them to the job site requires special forms, handling procedures, and transportation planning(see video). A video describing the precasting process is provided. A project site issue is the picking of the beam from the transporter and placing it on the bridge caps. This requires careful crane utilization planning at the site by the contractor. See video of this operation.

Graphics: See Picture of Bulb Tee Beam

Steel

Use of Seismic Isolation Bearings

Guideline: The cost of seismic isolation bearings should be reviewed against the cost of additional rebar to resist forces resulting from the use of conventional, confined neoprene bearing pads.

Qualifiers: The designer must check the substructure to assure it is still capable of carrying the higher earthquake forces.

Exceptions: None

Benefits: Net reduction in the cost of a system to withstand seismic forces.

Reasons: While a rather dramatic reduction in seismic force is available through the use of isolation bearings, they cost about 4 times as much as standard bearings.

Examples: On a recent bridge project in earthquake zone B, The cost of DIS isolation bearings was $100,000. While such bearings dramatically reduce the seismic force applied to the top of a pier cap, the designer should check the cost of additional concrete and steel required to resist the higher forces that would result from the use of standard reinforced neoprene bearings. Standard bearings should be designed to handle the higher forces, all the elastic movements from the earthquake, and provided in a recess to form an effective limit stop. This recess is to prevent the structure from moving off its bearings when expected elastic movements are exceeded. In this case the cost of additional reinforcing and concrete was minimal, due in part to a reduction in the width of the supporting pier, and hence the period of the structure. The standard bearings cost $20,000. and a net savings of $80,000. was realized on the job.

Studies and research have shown that in seismic zones 1&2 the use of wider bearing widths and rollers is an economical alternative. For seismic zone 3 and other bordering seismic zone 2 areas a restrainer will be required at these bearings to restrict the amount of movement.

Graphics: None

Reduce Column Width to Lower Seismic Forces

Guideline: In seismic zones, consider reducing pier column widths in the transverse direction to lower the period of the structure and hence the load which must be resisted during an earthquake.

Qualifiers: None

Exceptions: None

Benefits: Lower cost of superstructure and supporting elements.

Reasons: The stiffer the pier elements in the transverse direction the smaller the period of the structure. A stiff pier can generate very high earthquake forces which must then be isolated or resisted. A smaller stem creates a more flexible structure. This may help eliminate the need for isolation bearings and lower the quantity of concrete and steel in the pier and supporting structures.

Examples: None

Graphics: None

Web Stiffener to Tension Flange Connection

Guideline: Weld stiffeners directly to the tension flange rather than to a bolted plate unless required to do so by AASHTO fatigue criteria.

Qualifiers: 1. The fatigue condition must be a class C to avoid use of the bolted plate.

Exceptions: 1. All fatigue classes below C.

Benefits: Eliminates the plate, drilling and bolting costs at each stiffener which can be welded directly to the tension flange. (a savings of about $8.50) per connection)

Reasons: Fatigue life is adequate for the design stress level and category rating.

Examples: See detail of bolt plate connection

Graphics: None

Plate Girder Spacing

Guideline: Designers should use the fewest number of plate girders compatible with deck design. A girder spacing of 10 feet should be considered a minimum for economical results.

Qualifiers: 1. For low girder numbers check AASHTO fracture critical requirements. Reference AASHTO publication, "Guide Specifications for Fracture Critical NonRedundant Steel Bridge Members."

Exceptions: None

Benefits: Up to 30% reduction in structural steel weight, and quantity of pieces to erect and forming cost between the beams.

Reasons: Wider girder spacing and deeper girders will generally result in lower structural steel weight. A 14 foot spacing and 10 inch deck has been achieved in other states.

Example: A welded plate girder bridge was designed according to Indiana standards (through 1992) and then redesigned according to the above criteria with the following results.

ITEM	Standard Design	Redesign
Girder Spacing	7' 10"	9' 3"
Number of Girders	5	4
Girder Depth	5' 6 1/2"	6' 6 1/2"
Number of Spans	Five	Five
Structural Steel/sf	42 lb/sf	29.5 lb/sf
Overhang Distance	2' 6"	4' 3"
Rebar Grade	40 ksi	60 ksi
Slab thickness	8.5"	8.5"

This resulted in a 25% savings in structural steel, a total of 250,000 lb savings. The change in grade of rebar enabled the increase in deck spans with no increase in rebar weight. The forming costs were reduced because it takes 25% less labor to fill 3 interior bays than it does 4.

Graphics: None

Setting Bridge Screed Grades

Guideline: Designers need to provide bridge deck screed grades along the beam line, not between beam lines.

Qualifiers: None
Exceptions: None

Benefits: Providing screed grades along beam lines is a straight forward process for the survey crew and makes it an easy and familiar process for the ironworker to install the forms.

Reasons: Bridge deck screed grades not specified along beam lines are impossible to locate and rather difficult to interpolate to the beam lines.

Examples: A video has been developed to explain the process of setting bridge deck screed grades. The designer should view the video which provides an explanation of the surveying procedures and and a perspective from an ironworker.

Graphics: None

Pipe, Manholes, Inlets, Catch Basins

End Section Toeplates

Guideline: Determine whether toeplates are to be used or not, specify clearly what is wanted, and apply the rule.

Qualifiers: None

Exceptions: None

Benefits: Savings of $50 to $150. per toe section which are typically specified, and purchased, but not installed.

Reasons: Toeplates are generally specified to prevent the vortex action of the water from undermining the pipe end section. The drawings and specs often call for them and they should be used and not eliminated in the field.

Examples: " Our lot has so many toe sections with state tags on them we could go into the scrap metal business. The drawings and specs call for them, and INDOT project engineers direct us not to put them on because they don't perform their intended purpose. At $50 to $150 each." (Contractors United)

Graphics:
See Toe Anchor Graphic

See engineered drawing of toe plate graphic.

Hoods on Catchbasins

Guideline: Clearly specify when hoods will be required on catch basins.

Qualifiers: None

Exceptions: None

Benefits: Reduced uncertainty and conflict in bid documents.

Reasons: More care should be exercised by engineers to avoid conflict and errors in this area.

Examples: The specification on the project we are bidding says hoods will not be required. But it has 200-type structures which the standard shows with hoods. Further, we know from experience that sanitary or combined sanitary and storm sewers normally have hoods. So do we research every one to be sure whether it is sanitary, or combined with sanitary and then include them because our experience tells us they will be needed. At $200 each, that adds up. (Contractors United)

Graphics: Picture of Curb Catch Basin Hood.

Boxed End Sections

Guideline: The necessity of boxed end sections should be investigated prior to use.

Qualifiers: None

Exceptions: None

Benefits: As much as $100,000. savings for each one that can be eliminated.

Reasons: By the time they are installed, boxed end sections on pipes may cost as much as the whole pipeline. They are normally installed for increased safety in the event of a vehicular impact. They provide a 3:1 slope if the car hits one rather than the old headwall. But, they have been installed on a side where a car would have to backup into one to hit it.

Examples: They may cost $100,000 and if at the end of a 50-ft slope, the chance of being hit is rather remote. Their necessity should be investigated. (Reith Riley)

Graphics: See drawing of box end section.

Bridge-Road Transition

Guideline: Include the upgrade of just enough approach road adjacent to a bridge to construct it.

Qualifiers: None

Exceptions: 1. If the upgrade can continue to an intersection, or other natural transition, it may be economically justifiable to do it with the bridge.

Benefits: Reduced cost for construction of the approach. It is more economical to upgrade the roadway in a road contract than a bridge contract.

Reasons: The design practice of improving a road 6-700 feet on either side of a bridge cost 2 to 2 and 1/2 times as much as the same work performed during the upgrade of the balance of the roadway. Mainline road work requires at least one half to 1 mile length to be productive. Just enough to put the bridge in is fine, but it is a waste to go beyond that because the road just necks down anyway, which eliminates any significant public benefit until the balance of the road is upgraded. (Switzer & Huckleberry 1983)

Examples: None
Graphics: See picture of this area.

Earthwork

Linear Grading

Guideline: Implement current linear grading policy into the plans and bidding documents.

Qualifiers: 1. None

Exceptions: 1. None

Benefits: Elimination of a vast quantity of unknowns and resulting uncertainty at bid time.

Reasons: Linear grading has a large amount of uncertainty. (Contractors United)

Examples: Linear Grading shall consist of earth wedging at the outside edge of a shoulder once the pavement has been resurfaced, widened, or replaced. Linear grading shall also consist of earth wedging behind guardrail to obtain the required earth backup for the posts. Linear grading shall also consist of median earth filling required for paving and placement of concrete median barrier. These types of earthwork shall not require benching. If the contract provides for a pay item for linear grading, the measurement for payment will be based on the length of roadway mileage (kilometerage) actually constructed to the lines, grades, and typical cross sections specified. All classes of excavation involved will not be measured for payment. Such classes of excavation will be considered as included in the pay item for linear. (Linear Grading Specifications, Section 203.27, paragraph C- " When either or both the plans and contract provide for an item of linear grading, the measurement for payment shall be based on the length of roadway mileage actually constructed to the lines, grades, and typical cross sections specified. All classes of excavation involved, including required borrow, will not be measured for payment, but will be considered for as included in the item for linear grading per mile(1.6 kilometer).)

Graphics: None

Bases

Bituminous Coated Base

Guideline: Do not specify bituminous coated 5-c #8 rock under asphalt for small sections which are surrounded by other types of bases.

Qualifiers: None

Exceptions: None

Benefits: More cost-effective repair and patching.

Reasons: Using bituminous coated 5C base material under asphalt for small sections which are surrounded by other types of bases are very expensive and don't appear to serve any useful purpose.

Examples: For example when widening an intersection. Half loads or even full loads are used to hold the heat. If there is only a half load requirement the material is very expensive. Eight ton loads are too small to go 20 miles. So a half load would be wasted just to hold the heat. (Reith Riley)

Graphics: See detail of intersection widening

See plan view where small quantities used.

Incidentals

Properly Size Manholes

Guideline: Size manholes at least large enough to avoid destroying the structure of the manhole when tying in specified pipes.

Qualifiers: None

Exceptions: None

Benefits: Reduces design errors, and change orders and jobsite delays and disruption which result from them.

Reasons: " Many times manholes are sized inappropriately for the pipes it is servicing. " (Contractors United)

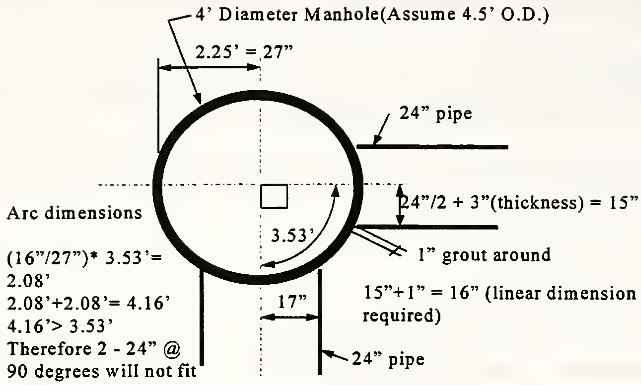
Examples: Ex. a 4-Ft diameter manhole for a 4-ft pipe. Or if 3 @24 inch pipes are put into a 4-ft manhole, you don't have a structure left.

See Manhole Detail A

See Manhole Detail B

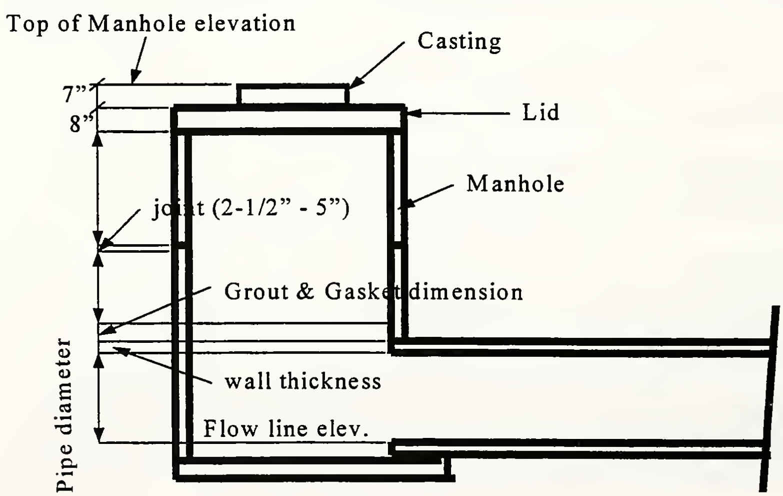
Graphics:

Example No. 1 - The below graphic example shows a 4' diameter manhole with two 24" pipes coming in at 90 degrees. The designer needs to check for dimensional clearance around the arc of the manhole. Review the sample calculations for this example.



Plan View

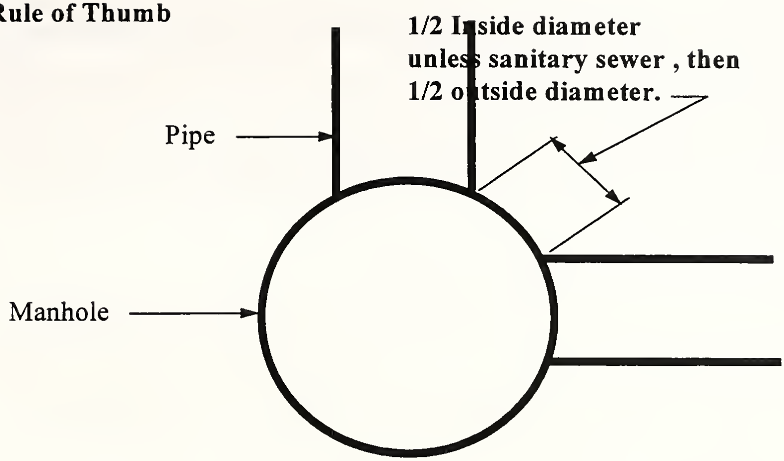
Example No.2 - This example is about checking vertical dimensions against flow line elevation. The pipe is layed out by using flow line elevations. The designer needs to verify this elevation as well as the manhole top elevation. The below graphic shows an example.



Elevation View

Example No. 3

Rule of Thumb



Plan View

"After checking manhole and pipes in both the vertical and horizontal dimensions the designer needs to check for the combination; because in three dimensional space a conflict could occur. Time spent in checking dimensions, fit, and elevations can eliminate potential field problems that are usually very expensive and time consuming to rectify."

(Horn Precast - Chap Backwell - 1995)

Interior and Exterior Drains

Guideline: Do not use interior(subsurface) drains, and install the exterior drain fabric as shown.

Qualifiers: None
Exceptions: None

Benefits: Avoids cutting up an efficient, mainline gravel installation process, with the associated time and cost impacts.

Reasons: "#8 and #53 gravels are currently installed using pavers. A subsurface drain with its associated filter fabric gets in the way of a paver's automatic trimmer. It often snags the fabric and tears out large sections which must be replaced by hand. Further, an additional drain at the center barrier does not appear useful. All that is necessary is one at the outside, the inside one is not needed." (Reith Riley)

Examples: Placing an interior subsurface drain at a crowned center or somewhere down the slope in the center between the crown and the edge drain is a waste of material and very costly to install because of the patchwork phasing required to dig the interior drain, place the #8 stone around it, and then place the impervious #53 gravel up next to it, without going over the top, before one can place the #8's on the top. It is very time consuming without any apparent added value. Typically, in the case of no barrier wall there is no interior drain. The designer should consider the question of why add a drain for a barrier wall if the roadway profile is the same.

See Interior Drain Detail

The engineer needs to consider contractor operations for installing gravel fill in the layout and details of the filter fabric.

See Exterior Drain Detail

Installation of filter fabric as shown around the exterior drain prevents infiltration, as well as, allowing the use of pavers to install the gravel. (Reith Riley)

Filter fabric is not required on all subsurface drains.

Cleanouts on Edge Drains

Guideline: Don't use cleanouts on edge drains. Simply check them following construction to be sure they are not crushed or full of construction rubble.

Qualifiers: None

Exceptions: None

Benefits: Eliminates the cost of the cleanouts and the disruption to mainline highway construction which they cause.

Reasons: Mainline highway economies of scale are available only when protruding items (like edge drain cleanouts), which tend to break up continuous functions, are eliminated. Further, edge drains which are properly installed seldom if ever plug up. To use them is costing the state a lot of money with no apparent benefit.

Examples: "We have removed or reworked hundreds of miles of edge drain and have never found one that was plugged up. Cleanouts on edge drains, which have recently started showing up on bid documents, do not appear necessary. If checked and clear (not crushed or full of construction rubble) after construction, the drains seldom if ever plug up. The cleanouts appear to be a waste of money." (Reith Riley)

Graphics: See picture of edge drain cleanouts

New Roadway Adjacent to Existing Road

Guideline: When designing a new roadway to replace an adjacent and parallel one, the designer needs to evaluate the drainage requirements during the construction phase.

Qualifiers: None

Exceptions: None

Benefits: Eliminate dangerous roadway conditions for the traveling public. Remove contractor uncertainty and expense for temporary drainage during the construction phase.

Reasons: When the new roadway elevation is higher than the existing pavement elevation, a potentially dangerous and troublesome condition can exist. With a higher roadway running parallel to the existing roadway, a dam is created preventing water from properly draining. In low areas water will not drain therefore creating a dangerous condition for traffic. Also, the fill in these areas can become saturated causing problems for the contractor. When this situation occurs the contractor will be required to install temporary drainage items to correct the problem. The contractor either assumes the cost for installing these temporary measures or if during the bidding phase he has been perceptive to recognize this condition, will include a cost in the bid. Either it will cost the contractor or the state. It can also create an hostile environment during the construction contract.

Example: See video of project where this occurred.

Impact on Adjacent Property Owners

Guideline: Modifying an existing road either through rehabilitation or constructing a new parallel roadway will impact adjacent property owners access.

Qualifiers: None

Exceptions: None

Benefits: Considering the implications during design will prevent potential changes from occurring during the

construction contract. It is more economical to include these requirements in the contract documents and receive bid costs then to issue a change order during construction.

Reasons: The designer should analyze the impact construction causes to adjacent property owner access. Just as important, are the needs of the property owner being considered? A business owner is concerned about access and confusion during construction. A homeowner may not want curbs at the entrance to his driveway because it would restrict the turning radius into his driveway. So if he owned a trailer or RV it would be difficult to turn in.

Example: See video clip of examples.

Concrete Paving

Longitudinal Joint Spacing on Ramps

Guideline: Don't install joints that are not needed.

Qualifiers: None
Exceptions: None

Benefits: Avoids all the detrimentals associated with joints in addition to their construction costs.

Reasons: " Arguments for the joint, include the need for a hinged joint to accommodate the wheel loading out there. But why introduce an additional joint with all the infiltration problems that creates, when random cracking doesn't occur anyway on 16 foot wide ramps?" (Reith Riley)

Examples: Break out tie bars are often specified for the longitudinal joint along a 4 ft inside shoulder. The use of tie bar baskets with a sawed joint has been given as an alternate to avoid random cracking. But, the joint is not necessary. See Longitudinal Joint Spacing Detail.

Graphics: See picture of joint work.

Paving Next to Median Barrier Wall

Guideline: Placing concrete pavement next to the median barrier wall requires the contractor to modify the paving machine.

Qualifiers: None

Exceptions: None

Benefits: Reducing the number of times a construction contractor modifies paving equipment saves time and money.

Reasons: The pavement strip next to the barrier wall is difficult to place because the contractor must modify the paving machine which requires both time and effort. The designer should make the pavement strip a uniform width on both sides the entire length of the barrier wall. By doing so, only requires the contractor to change and setup the paving machine one time.

Example: See picture of concrete paving machine

See video of contractor placing concrete pavement next to barrier wall.

Endnotes

1 (Popup)
Design Memorandum No. 24, June 13, 1994 Re:Environmental Permit Requirements

ENVIROMENTAL PERMITS AND REQUIREMENTS

A. **FAA Permit**. Required when a permanent installation such as a high mast lighting tower, or construction equipment such as cranes or derricks is adjacent to a public airport. Such installation or equipment extends to a greater height than an imaginary surface extending outward and upward at one of the slopes as follows:

1. 100 to 1 for a horizontal distance of 20,000 feet (6100 m) from the nearest runway of an airport which has at least one runway of at least 3,200-feet (975 m) long.
2. 50 to 1 for a horizontal distance of 10,000 feet (3050m) from the nearest runway of an airport whose longest runway is under 3,200 feet (975 m) long.
3. 25 to 1 for a horizontal distance of 5,000 feet (1525 m) from the nearest landing or takeoff area of a heliport.

B. **IDEM 401 Water Quality Certification**. Required on every project which is covered by a U.S. Army Corps of Engineers nationwide permit (14), (23), or (26).

C. **IDEM Open Burning Permit**. Required only when the contractor is permitted to burn. If the area to be cleared is greater than 4 acres (1.6 ha), the Department will apply for this permit. If the area to be cleared is 4 acres (I. 6 ha) or less, the contractor shall apply for this permit. This application will be made only when it is determined that open burning is the only feasible method of clearing.

D. **IDNR Construction in a Floodway Permit.** Required when the drainage area is greater than or equal to 50 square miles (130 km) in a rural area, or 1 square mile (2.6 km") in an urban. area.

E. **IDNR Lake Preservation Act Permit.** Required when construction is being done at a public fresh water lake. The work extends to the shoreline or extends lakeward of the shoreline.

F. **National Pollutant Discharge Elimination System Permit.** Required when there is a point source discharge of effluent from a rest area sewage treatment plant.

G. **Rule 5 submission**. Required when the area of grading is 5 acres (2 ha) or greater. An Erosion Control Plan must be filed, but a Notice of Intent letter is issued in lieu of a permit.

H. **United States Army Corps of Engineers Levee Permit**. Required when construction affects a levee system which is owned by the Corps 'of Engineers.

I. **United States Army corps of Engineers Section 404 Permit.** Required when a discharge of earth or construction material is made into waters or wetlands of the United States.

J. **United States coast Guard Bridge Permit.** Required on projects which cross navigable waterways. The list of such navigable waterways is shown below. The Design Division's

Hydraulics Unit will provide the location of the Upper Limit.

K. **United States Coast Guard Construction, Dumping, and Dredging Permit.** Required when construction of other than bridges, or dumping or dredging operations occur in navigable waterways.

II. INDIANA NAVIGABLE WATERWAYS WHICH REQUIRE U.S. COAST GUARD BRIDGE PERMIT

WATERWAY	UPPER LIMIT
Anderson River	Mile 6.0 (Kilometer 9.7)
Crooked Creek	Mile 7.7 (Kilometer 12-4)
Cypress Creek	Mile 0.8 (Kilometer 1.3)
Great Miami River	only on bend of the river which is in the State of Indiana from about Mile 0.5 to Mile 1.5 (Kilometer 0.8 to Kilometer 2.4)
Indian Creek	Mile 4.8 (Kilometer 7-7)
Little Blue River	Mile 10.6 (Kilometer 17.1)
Little Oil Creek	Mile 4.4 (Kilometer 7-1)
McFadden Creek	Mile 2.3 (Kilometer 3.7)
Ohio River	Entirely within navigable limit
Wabash River	Mile 95.0 (Kilometer 152.9)

2 (Popup)

GENERAL U.S. ARMY CORPS OF ENGINEERS SECTION 404 PERMIT ACTIVITIES

The following is a listing of General Permits as established by the U.S. Army Corps of Engineers for the State of Indiana.

ACTIVITY	SCOPE OF WORK
A. Placement of poured in place concrete.	Construction of structures of length of 100 feet (30 m) or less using poured in place concrete as the primary building material.
B. Removal of sediment at intake structures.	Dredging limit to an area of less than 200 square feet ($19m^2$)
C. Construction or maintenance of utility lines.	Placement of fill is backfilled to orginal contours. The addition of 300 cubic yards ($230m^3$) of riprap bank protection is permitted.
D. Installing riprap fill material as bank protection and placement of other fill associated with the repair or restoration of levees.	Primarily for slope protection on the riverward side of levees.

E. Placement of fill in connection with bridge construction — Miscellaneous combination of fill not to exceed 1,000 cubic yards (760 m^3) in stream with drainage area> 50 square miles (130km^2), or 500 cubic yards (380 m^3) in stream with equal to or smaller drainage area.

* The special conditions which apply to each General Permit are available from the Design Division's Permits Section.

3 (Popup)

DEFINITIONS USED IN SECTION 404 PERMIT APPLICATION PROCESS

A. Categorical Exclusion, or CE. The types of projects which are typically considered to be CE's are as follows:

1. Access control
2. Added travel lanes with little or no right-of-way take
3. Bridge rehabilitation
4. Bridge replacement
5. Drainage correction
6. Erosion and landslide control
7. Guardrail and lighting
8. Intersection improvement
9. Railroad crossing improvement
10. Rest area modernization and construction
11. RRR
12. Safety improvements
13. Sight distance correction
14. Signalization and signing
15. Small structure replacement
16. Weigh station modernization and construction.

B. Draft/Final Environmental Impact Statement, or DEIS/FEIS. The types of projects which are typically considered to be DEIS's/FEIS's are as follows:

1. Construction of a new controlled access freeway
2. Construction of 4 or more lanes on a new location
3. Project with a significant adverse impact on the human environment.

C. Environmental Assessment/Finding Of No significant Impact, or EA/FONSI. The types of projects which are typically considered to be EA/FONSI's are as follows:

1. Added travel lanes involving acquisition of large amounts of right-of-way and a considerable number of relocations.
2. Construction of new roadways.

D. Headwaters of the United States. Rivers, streams, and their lakes and impoundments, including adjacent wetlands, which are part of a surface tributary system of navigable waterways of the United States, upstream of that point on such river or stream at which the average flow rate

is less than 5 cubic feet per second (0.14 m3/s).

E. Notification. Where required by the terms of a nationwide permit, the applicant for a nationwide permit must notify the U.S. Army Corps of Engineers in writing as early as possible prior to the construction of the project work. Specific information concerning the proposed project must be included in the notification. The Federal Register of Friday, November 22, 1991, Vol. 56, No. 226, pages 59145-46, 33 CFR 330, Appendix A, General Conditions (13) includes detailed information concerning what is to be included in the notification.

F. Ordinary High Water, or OHW. The line showing on the shore which is established by fluctuations of water and is indicated by physical characteristics such as clear, natural lines impressed on the waterway bank, shelving, changes in the character of the soil, destruction of terrestrial plants, the presence of litter or debris, or other appropriate means that consider the characteristics of the surrounding area.

G. Special Acquatic Sites. Mudflats, refuges, riffle and pool complexes, sanctuaries, vegetated shallows, and wetlands.

H. Waters of the United States. Each river, stream, creek, intermittent tributary, pond, impoundment, lake, or wetlands is considered to be part of the waters of the United States.

I. Wetlands. Bogs, marshes, sloughs, and swamps are other terms used to describe these areas. Floodplains, or areas where water stands on, at, or near the groundline may be considered as suspected wetlands. Guidelines as established by the U.S. Army Corps of Engineers indicate that a wetlands must have all of the characteristics as follows:

1. A preponderance of water tolerant plants
2. Hydric soils
3. Water on, at, or near the surface of the ground during a specified portion of the growing season.